PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

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THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

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NOTICE

This number of the PROCEEDINGS is published about two weeks ahead of its regular date of issue in order that the last six Convention papers, contained herein, may be available to the Institute membership prior to the Convention.

All of the Convention papers except these six have been printed in the May and June numbers of the PROCEEDINGS.

Annual Convention, Cooperstown, N.Y., June 23-27, 1918

Institute Headquarters

The official headquarters of the Institute during the convention will be at the Hotel O-te-sa-ga, where the technical sessions will be held. Members are requested to register at Institute headquarters on their arrival in Cooperstown. The following program has been arranged:

PROGRAM

Monday, June 23

9:00 P.M.

Reception and dance, Hotel O-te-sa-ga.

Tuesday, June 24

10:00 A.M.

1. President's Address, by Ralph D. Mershon.
2. Introduction of President-elect, C. O. Mailloux.

10:30 A.M.

3. *A Suggestion for the Engineering Profession*, by William McClellan.

Telegraphy and Telephony Committee—

4. *Test of an Artificial Aerial Telephone Line at a Frequency of 750 Cylces per Second*, by A. E. Kennelly and F. W. Lieberknecht.
5. *Automatic Methods in Long-Distance Telephone Operation*, by H. M. Friendly and A. E. Burns.

Electrochemical Committee—

6. *Electrolytic Corrosion of Iron in Soils*, by Burton McCollum and K. H. Logan.

8:00 P.M.

Educational Committee—Report on Industrial Education.

7. *Introduction*, by Henry H. Norris.
8. *The National Association of Corporation Schools*, by F. C. Henderschott.
9. *Vocational Education in Philadelphia and Vicinity*, by A. J. Rowland.
10. *Vocational Training in the Far West*, by Robert Sibley.
11. *The Pennsylvania Railroad Company Apprentice Schools*, by John Price Jackson and J. W. L. Hale.

Wednesday, June 25

10:00 A.M.

High-Tension Transmission Committee—

12. *Suggested Specifications for Testing High-Tension Insulators*, by J. A. Sandford, Jr., F. W. Peek, Jr., and Percy H. Thomas.
13. *Constant Voltage Transmission*, by H. B. Dwight.

14. *Theory of the Non-Elastic and Elastic Catenary as Applied to Transmission Lines*, by C. A. Pierce, F. J. Adams and G. I. Gilchrest.

2:00 P.M.

Industrial Power Committee—

15. *The Behavior of Synchronous Motors during Starting*, by F. D. Newbury.
16. *Commutating Pole Saturation in Direct-Current Machines*, by H. E. Stokes.
17. *The Industrial Use of Synchronous Motors by Central Stations*, by J. C. Parker.
18. *Electrical Requirements of Certain Machines in the Rubber Industry*, by C. A. Kelsey.

8:00 P.M.

Board of Directors' Meeting

Thursday, June 26

10:00 A.M.

Power Station Committee—

19. *Standardization of Method for Determining and Comparing Power Costs in Steam Plants*, by H. G. Stott and W. S. Gorsuch.

Electric Lighting Committee—

20. *Automatic Substations*, by H. R. Summerhayes.
21. *Converting Substations for Basements and Sub-Basements*, by B. G. Jamieson.
22. *Operation of Frequency Changers*, by N. E. Funk.

AFTERNOON

Meeting of Executive Committee of Committee on Organization of International Electrical Congress, San Francisco, 1915.

8:00 P.M.

Presentation of Edison Medal.

8:30 P.M.

Conference of Officers and Section Delegates on Institute affairs. All members welcome.

Friday, June 27

10:00 A.M.

Electrophysics Committee—

23. *The Electric Strength of Air—IV*, by J. B. Whitehead and T. T. Fitch.
24. *The Positive and the Negative Corona and Electrical Precipitation*, by W. W. Strong.
25. *Law of Corona and the Dielectric Strength of Air—III*, by F. W. Peek, Jr.
26. *An Oscillographic Study of Corona*, by Edward Bennett.

Entertainment

NOTE.—The Entertainment Committee will maintain an office during the convention at registration headquarters in the Hotel O-te-sa-ga, where representatives of the committee will be prepared to give full information concerning the entertainment features. Watch the bulletin board for each day's features.

Monday, June 23, 9:00 p.m. Reception and dance in Ball Room of the Hotel O-te-sa-ga, to which all members and their guests are invited.

Tuesday, June 24, 2:30 p.m. Preliminaries in golf and tennis tournaments. Those desiring to enter will register their names with the committee by Tuesday noon. A ball game will also be played Tuesday afternoon.

Wednesday, June 25, 10 a.m. An automobile trip around Otsego Lake has been arranged for the ladies.

Wednesday, June 25, 8:00 p.m. Ladies' bridge tournament.

Thursday, June 26, 10:00 a.m. Court golf tournament for the ladies.

Thursday, June 26, 2:30 p.m. Finals in golf and tennis tournaments.

Thursday, June 26, 4:00 p.m. Steamer excursion on Otsego Lake.

The committee is arranging for suitable prizes in the various tournaments.

A prize will also be given for the largest fish caught during the convention.

The country around Cooperstown is very picturesque and offers many attractive walks and drives. Facilities will be provided for boating, swimming and fishing. Information regarding automobile and trolley trips will be available.

Transportation Arrangements

No special transportation rates are available.

Cooperstown is in Otsego County, N. Y., and can be best reached over the Delaware and Hudson Company Railroad, from Albany, or over the Otsego & Herkimer Railroad from Herkimer, which is on the main line of N. Y. C. & H. R. R.R., 14 miles east of Utica and 80 miles west of Albany.

TRAIN SCHEDULE

FROM ALBANY, N. Y. TO COOPERSTOWN

Leave Albany	*Due Cooperstown*
Week Days	
7:30 a.m.	11:00 a.m.
10:00 a.m.	1:20 p.m.
*4:30 p.m.	7:30 p.m.
Sundays	
8:30 a.m.	1:05 p.m.
*4:30 p.m.	8:00 p.m.

* Parlor car attached to this train.

FROM HERKIMER, N. Y. TO COOPERSTOWN

(High speed interurban electric line, carrying baggage.)

Hourly service, 6:51 a.m. to 7:51 p.m. inclusive. Also parlor car 8:30 a.m. and 3:36 p.m. Running time Herkimer to Cooperstown, two hours.

Special Arrangements for Through Sleepers

In order to reach Cooperstown on the afternoon of Monday, June 23, members should arrive in Albany in time for the D. & H. train leaving Albany at 7:30 a.m., June 23.

For the purposes of transportation, the membership may be divided into three (3) groups:

(A) Boston and New England.

(B) New York and south including Philadelphia, Baltimore, Washington, Pittsburgh, and Atlanta.

(C) Buffalo and west including Cleveland, Columbus, Chicago, Cincinnati, St. Louis and west.

These three (3) groups will meet at Albany.

Members in group A should leave Boston on the Boston & Albany train leaving South Station at 11:15 p.m., Sunday, June 22. Applications should be made not later than June 18 to Mr. C. E. Colony, B. & A. R. R., 298 Washington Street, Boston, Mass.

Members in group B should arrive in New York in time to take New York Central train leaving Grand Central Terminal on Sunday night (12:45 a.m. Monday morning, June 23). Applications for space in sleeper should be made not later than June 18 to Mr. W. F. Lifsey, N. Y. C. & H. R. R. R., 1216 Broadway, New York City.

Members in group C, from the west, should leave Chicago on train leaving Chicago via Lake Shore at 9:05 a.m. Sunday, June 22. Applications should be made not later than June 18 to Mr. George Thompson, L. S. & M. S. R. R., 100 South Clark Street, Chicago, Ill.

Provided a sufficient number of applications are received on or before June 18 by the district passenger agents above-mentioned, arrangements will be made to have special through sleepers from their respective cities attached to the D. & H. train leaving Albany at 7:30 a.m., June 23.

For information concerning routes, train schedules, rates and equipment other than contained herewith, members should communicate with Local Passenger Agents in accordance with the appended list.

DIST. PASSENGER AGT. AND ADDRESS	ROUTING
Boston	
C. E. Colony, B. & A. R.R. 298 Washington St., Boston.	(a) Boston & Albany to Albany.
O. W. Jordan, 196 Washington St., Boston.	(b) Boston & Maine to Albany to Coopers-town via Delaware & Hudson.
Chicago	
C. C. Clark, Michigan Central R.R., 228 So. Clark St., Chicago.	(a) Michigan Central to Buffalo via N. Y. Central to Albany via Delaware & Hudson to Cooperstown.
Geo. Thompson, Lake Shore R.R. 100 So. Clark St., Chicago, Ill.	(b) Lake Shore & Michigan Southern to Buffalo via New York Central to Albany, via D. & H. to Cooperstown. (c) Either (a) & (b) to *Herkimer* instead of Albany, via Otsego & Herkimer Railroad Co., (trolley line—30 miles) to Cooperstown.
New York	
W. V. Lifsey, 1216 Broadway, New York City.	(a) New York Central to Albany. (b) Day and night boat lines to Albany. Tickets reading via New York Central & Hudson River or West Shore railroads between New York and Albany or Troy, are accepted on the Peoples or Citizens Line steamers without extra charge. Night boats leave Pier 32 N. R., foot Canal Street, New York City at 6 p.m. arriving at Albany 6 a.m. Day boats leave Pier 30, N.R., foot Desbrosses St., N. Y. City, at 8:40 a.m. and West 129th St. at 9:20 a.m.
W. J. Scott, 1354 Broadway, New York City.	(c) West Shore R.R. to Albany. (a, b, c) Albany to Cooperstown via Delaware & Hudson.
Pittsburgh	
E. Youngman, Penn. R.R. Pittsburgh, Pa.	(a) Pittsburgh via Penn.R.R. to Wilkes-Barre via Delaware & Hudson to Cooperstown.
W. B. Morris, Pittsburgh & Lake Erie R.R. Pittsburgh, Pa.	(b) Pittsburgh via Pittsburgh and Lake Erie R.R. to Buffalo, via New York Central to either Herkimer or Albany. See (c) under Chicago. (c) Pittsburgh to Philadelphia to New York via Penn. R.R. New York to Cooperstown. (See New York.)
Washington	
S. B. Hege, B. & O., Calvert & Baltimore Sts., Washington, D. C.	(a) Baltimore & Ohio to N. Y. New York to Cooperstown (see New York).
Wm. Pedrick, Jr., Penn. R.R., Baltimore.	(b) Pennsylvania R.R. to New York,—New York to Cooperstown (see New York.)
St. Louis	
R. C. Kennedy, 715 Olive Street, St. Louis, Mo.	New York Central lines to either Herkimer or Albany (see (*c*) under Chicago).
J. B. Modesett, Penn. R.R., St. Louis, Mo.	Penn. R.R. to Wilkes-Barre to Cooperstown, via Del. & Hudson.

AUTOMOBILE ROUTES

To those desiring to reach Cooperstown by automobile, the following routes are recommended.

Boston to Cooperstown

Boston — Worcester — Springfield — Jacobs Ladder — Pittsfield — Albany —Schenectady — Amsterdam — Tribes Hill — *detour to Fonda* —Cooperstown.

Buffalo to Cooperstown

Batavia — Rochester — Canandaigua — Auburn — Syracuse — *Morrisville — Waterville — Richfield Springs — Cooperstown.

**Alternative:* Morrisville — Hamilton — De Ruyter— Earlville— Burlington — Cooperstown.

New Haven to Cooperstown

Waterbury—Torrington—Norfolk—Stockbridge—Lenox —Pittsfield —(see Boston to Cooperstown).

New York to Cooperstown

Poughkeepsie — Rhinebeck — Hudson— Albany —(see Boston to Cooperstown).

Alternative: New York — Newburgh — Kingston — (ferry to Rhinebeck) — Hudson — Albany — (see Boston to Cooperstown).

Ferry schedule from Kingston to Rhinebeck:

Week Days. Leave Kingston (Rondout): 6:35 a.m., 7:30 a.m., 9:00 a.m., 9:45 a.m., 10:35 a.m., 11:40 a.m., 12:20 p.m., 12:50 p.m., 1:30 p.m., 2:30 p.m., 3:15 p.m., 3:55 p.m., 4:40 p.m., 5:20 p.m., 6:05 p.m., 6:35 p.m.

Sunday Schedule. Same as week days except 6:35 a.m.

Pittsburgh to Cooperstown

Butler—Mercer—Meadville—Cambridge Springs — Erie — Buffalo — (see Buffalo to Cooperstown).

Philadelphia to Cooperstown

Easton — Delaware Water Gap — Scranton — Binghamton — Unadilla — Oneonta — Cooperstown.

For more detailed information concerning above routes consult The Blue Book and Automobile Club books.

Important Notice

It is essential to the comfort and convenience of members attending the Convention and to the success of all these arrangements that immediate attention be given by everybody to secure the accommodations desired. A representative of the Convention Committee will be at Institute Headquarters during the Convention to advise with and assist members and guests regarding their return accommodations.

Delegates of Sections

Official delegates of Sections are requested to register as such at Institute headquarters, so that they may receive the special badges that will be provided for them.

Arrangements will be made for a separate room in which the delegates may take luncheon together each day, thus affording opportunity for informal discussion of Ins itute and Section affairs.

Hotel Arrangements

Each member should arrange for his own hotel accommodations, and early application is desirable. The Institute will make its headquarters at the Hotel O-te-sa-ga, and members desiring accommodations at this hotel should communicate with Mr. Paul L. Pinkerton, Manager, Hotel O-te-sa-ga, Cooperstown, N. Y. The hotel management has made the following rates, on the American plan, for members and guests who attend the convention: Single rooms, $5.00 per day per person; with bath, $6.00. Double rooms, for two persons, $5.00 per day per person; with bath $5.50 per day per person.

A large number of suites for the accommodation of two, three and four gentlemen are available at the O-te-sa-ga, and members will find it mutually advantageous to make their reservations accordingly.

Accommodation will also be available at the Fenimore Hotel, the Hoffman House, and Otsego Hall, at prices ranging from $2.00 to $3.50 per day. All correspondence on the subject of reservations should be addressed to the hotel management in each case.

Registration

Each member and guest, upon registration, will receive a badge bearing his or her name, to be worn during the convention for the purpose of identification. The registration headquarters will be at the Hotel O-te-sa-ga, and the members are earnestly requested to register themselves and their guests promptly on arrival.

Pacific Coast Convention, Vancouver, B. C., September 9-11, 1913

The following program of papers has been arranged for the Pacific Coast Convention of the Institute to be held in Vancouver, B.C., September 9–11, 1913, by Mr. F. D. Nims, chairman of the papers committee:

Fuel Oil Burning as Applied to Central Station Practise.

Analysis of Wave Forms.

Electric Logging on the Pacific Coast.

Illustrated lecture on *Secondary Distribution by Cable.*

Stresses and Strains in Transmission Lines.

High-Tension Distribution.

Scientific Management.

The entire program as tentatively arranged will be as follows:

MONDAY, SEPTEMBER 8

Afternoon—Office open for registration.

TUESDAY, SEPTEMBER 9

Morning—Office open for registration. Opening Meeting. Address of welcome by Premier of British Columbia, followed by paper and discussion.

Afternoon—Paper and discussion. Automobile and car trips, seeing Vancouver, for ladies of the party.

Evening—To be left free for theaters and private entertainment.

WEDNESDAY, SEPTEMBER 10

Morning—Paper and discussion.

Afternoon—Paper and discussion. Automobile trip to Capilano Canyon for the ladies.

Evening—Illustrated lecture.

THURSDAY, SEPTEMBER 11

Morning—Paper and discussion.

Afternoon—Paper and discussion. Automobile trip for the ladies around Stanley Park and Marine Drive, followed by tea party.

Evening—Banquet.

FRIDAY, SEPTEMBER 12

Excursion to Stave Falls.

SATURDAY, SEPTEMBER 13

Excursion to Lake Buntzen.

It is expected that the papers and the complete program will be printed in the August issue.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before July 25, 1913.

Blaisdell, B. H., Manila, P. I.
Burns, Thomas, (Member), Prince Rupert, B.C.
Couch, D. H., Mayaguez, P. R.
Doss, Albert C., Hamburg, Ark.
MacMurray, C. F., Colon, Panama.
Marshall, E. C., Pittsburgh, Pa.
Mentz, H. A., Memphis, Tenn.
Parkhurst, A. F., Brooklyn, N. Y.
Pierson, C. A., Kansas City, Mo.
Schulenburg, W. A., Mexico, D. F.
Shaw, H. C., Chicago, Ill.
Smith, G. R., (Member), New York, N. Y
Stewart, D. W., Dunedin, N.Z.
Takahashi, M., Champaign, Ill.
Takakuwa, K., Osaka, Japan.
Woollen, A. H., Boston, Mass.

Total, 16.

Dinner to President-Elect Mailloux

A dinner in honor of President-elect C. O. Mailloux was given by Past-President Gano Dunn at the University Club, New York, on the evening of May 28. The guests, about twenty-five in number, included six past-presidents, several members of the Board of Directors, and others prominent in Institute affairs. All present took occasion to felicitate Mr. Mailloux upon his election and to pledge their hearty cooperation during his coming administration.

INJUNCTION DENIED

To the membership of the American Institute of Electrical Engineers:

In view of a possible early decision in the suit against the Institute and the Board of Directors relating to the Special Section of the constitution, the following resolution was adopted at the last meeting of the Board on May the 20th:

"*Resolved*, that a committee, consisting of the four senior Managers, be appointed to receive, for the Board of Directors, the decision of the Supreme Court in the case against the Institute, and that this committee have full power, after conference with the legal counsel of the Institute, to prepare and publish a statement in the PROCEEDINGS."

The decision was handed down on June the 10th in an opinion by Mr. Justice Page, the text of which is printed in full below.

The considerations which led to the bringing of this suit are fully presented in the letter addressed to the membership by President Mershon and published in the April PROCEEDINGS.

The considerations which have guided the Board in its treatment of the Special Section are well presented in the brief submitted to the Court by Messrs. Parker & Aaron. This brief is, therefore, also included below.

It will be observed that the opinion rendered by the Court fully sustains the action of the Board under the Special Section.

For the Board of Directors,

H. H. BARNES, JR.,
R. G. BLACK,
W. S. RUGG,
C. E. SCRIBNER.

By Mr. Justice Page. Duncan v. Am. Inst. of Electrical Engineers.—

This is a motion to enjoin the Board of Directors of the American Institute of Electrical Engineers from transferring certain members of the said society from the grade of members to that of fellows, and from the grade of associates to members. The question involved is the interpretation of an amendment of the constitution of the said society adopted May 21, 1912 and known as the special section. Changes were made at that time in the various forms of membership in the society. Prior thereto there had been only two classes of active membership therein, namely, members and associates. The new amendments to the constitution created an additional highest grade of member known as "fellow," and provided the necessary qualifications for this new class. This meant that the vast number of men who were formerly members of the society of the highest grade were at once lowered to the second grade by the creation of the new higher grade of "fellow." The majority of these men were eligible for the grade of fellow and would naturally desire to enter the ranks of the higher grade. Provision was made for their doing so in the aforesaid special section, which reads as follows: "Special Section. Any person who shall be a member at the time this group of amendments is adopted shall on written request to the society prior to May 1, 1913, without the payment of the transfer fee or increase of life membership fee, have the right to become a fellow, provided he refers to at least five fellows or members, who upon inquiry shall certify that he meets the requirements of the grade of fellow as herein defined. Any person who shall be an associate at the time this group of amendments is adopted shall, on written request to the secretary prior to May 1, 1913, without the payment of the transfer fee or increase of life membership fee, have the right to become a member, provided he refers to four fellows or members, who upon inquiry shall certify that he meets the requirements of the grade of member as herein defined." The board of directors in acting upon applications for transfer from the grade of member to fellow and from the grade of associate to member under this special section have regarded the section as a complete and independent provision temporarily made for that

purpose, and where the applicant has complied with the said section in regard to certification by his fellow members have made the transfer without further inquiry or examination. The plaintiffs claim that the special section should be read in conjunction with the other provisions of the constitution concerning transfer, and that applications for transfer under its provisions should be referred to the board of examiners for investigation as to the professional qualifications of the applicants. Upon an examination of the special section together with the other portions of the constitution of this society, I am of the opinion that it is independent of all other provisions of the constitution and by-laws, and provides a convenient practical and temporary method whereby old members of the society who are eligible for transfer to the grades of fellow and member may quickly assume their new title and standing without being compelled to go through the routine provided for in the other sections of the constitution. While I am not prepared to say that the interpretation sought to be placed upon the section by the plaintiffs is not arguable and may not at the trial of the action be sustained by the proofs, from the papers before me the right to an injunction *pendente lite* is not established and the injunction will be denied.

Brief on Behalf of American Institute of Electrical Engineers

Statement of Facts

Prior to May 21st, 1912 there were but two grades of active Members in the Institute, the lower grade being designated as Associates and the higher as Members. During four years the question of establishing an additional grade, conforming to the well known practice of other important learned bodies had been the subject of careful consideration by the Board of Directors and special committees dealing with the question.

The creation of a new and highest grade of active Membership under the name of Fellow, would obviously have the practical effect of reducing the dignity of the grade of Member which was the then highest grade of active Membership. It was recognized however, that the learned gentlemen then admitted to the highest honors of the Institute, after having undergone the careful scrutiny of the Examining Committee and Directors, in general were qualified for and should form the nucleus of the newly established highest grade and it was sought to provide practical and reasonable methods for their entrance. Naturally the suggestion arose that Members might, without any motion or consent on their part, be forthwith transferred to the grade of Fellow. In view, however, of the fact that the annual dues of Fellows were made higher than the then existing dues of Members, it was not deemed proper to fasten upon a Member, without his consent, such enlarged financial obligations. Therefore, it was with obvious justice, concluded that some initiative or consent of the Member to the transfer should be made. The same reason for requiring the consent of an Associate to the assumption of enlarged financial responsibility applied, since the annual dues of the new grade of Member were larger than those of the then existing grade of Associate. In addition it was felt desirable to provide for proper scrutiny of the qualifications of Associates seeking transfer to the newly established grade of Member which while being just to the applicant and the Institute, should at the same time be feasible. It was felt that on the adoption of the new grade there would be a large body of Associates availing themselves of the opportunity of transfer to the higher grade of Member and that likewise the entire body of then existing Members would practically be transferred to the grade of Fellow.

Under the previously existing constitution, it was provided that applications for transfer be passed upon in the first instance by a Board of Examiners con-

sisting of five Members and that their report be submitted to the Board of Directors of the Institute who should thereupon pass upon the proposed transfer, any two negative votes of Directors being sufficient to prevent the transfer.

The estimate which was issued in March, 1912, by Mr. Gano Dunn, the President, in a communication to all the Associates and Members of the Institute when the proposition to adopt the amendment to the constitution was pending, shows that it was expected that there would be promptly transferred 705 Members to the grade of Fellow and 2,257 Associates to the grade of Member. (See Exhibit "A" annexed to answering affidavit and diagrammatical illustration). Thus, it will be noted that it was anticipated that there would be over 2,950 transfers to be promptly dealt with. The Board of Examiners consisted of five men engaged actively in their own important business affairs, and it was obviously impossible for those five men in the course of a few months, to make any inquiry worthy of the name of examination upon about 3,000 Associates and Members scattered over every part of the Union and places beyond, and upon their honor, report their conclusions to the Institute. Therefore, the learned gentlemen charged with the responsibility of making recommendations, being also by training and achievement practical men of affairs, realized that it would overwhelm and submerge the Board of Examiners to impose upon them the unbearable obligation of passing upon the vast influx of applicants for transfer who would be stimulated into early action by the adoption of the Special Section. The following feasible and reasonable plan was therefore proposed, viz., first, that any person who at the time of the adoption of the Special Section was a Member should have the right of being transferred to the grade of Fellow upon the filing by five Fellows or Members of certificates that he possessed the requisite qualifications; and secondly, that any then existing Associate should have the right of transfer to the grade of Member upon the filing by four Fellows or Members of like certificates, and accordingly the following Special Section of the constitution was proposed and adopted:

"SPECIAL SECTION: Any person who "shall be a Member at the time this "group of amendments is adopted, "shall, on written request to the Sec-"retary prior to May 1, 1913, without "the payment of the transfer fee, or "increase of life membership fee, have "the right to become a Fellow, pro-"vided he refers to at least five Fel-"lows or Members who, upon inquiry, "shall certify that he meets the require-"ments of the grade of Fellow, as here-"in defined.

"Any person who shall be an Associate "at the time this group of amendments "is adopted shall, on written request "to the Secretary prior to May 1, 1913, "without the payment of the transfer "fee, or increase of life membership "fee, have the right to become a Mem-"ber, provided he refers to four Fel-"lows or Members who, upon inquiry, "shall certify that he meets the re-"quirements of the grade of Member, "as herein defined.

"The dues of Members and Asso-"ciates transferred under the provi-"sions of this Special Section shall not "be increased until May 1, 1913."

It will be noted that every person availing himself of the provisions of that Special Section had already been scrutinized by the Board of Examiners and the Directors before being admitted to entrance into the grade which he then possessed.

It will also be noted that the certifiers were required to be men who had achieved the then existing highest rank of Active Membership or who had been advanced to the grade of Member, either by the scrutiny and approval of old Members or by the scrutiny and approval of the regular Board of Exam-

iners. It was with perfect confidence that the responsibility imposed by the Special Section to meet the emergency during the ten months' period was delegated to the Members. It was felt that whether they were labeled a Board of Examiners or not, the character of the men or their work would not change and that in either case they would realize the responsibility resting upon them and would discharge it with honor and fidelity. It will be borne in mind that the Special Section was, as its name indicates, a Special Section applying especially and only to persons affiliated with the Institute on a particular date, viz., May 21, 1912, and that it was to be operative only for a particular period of time, viz., from the time the Special Section went into effect, viz., June 20th, 1912, to May 1st, 1913, a period of about ten months.

Action was taken under the Special Section and a large number of transfers have been made. Now, three weeks before the Special Section expires by limitation, come the plaintiffs alleging that the Special Section does not mean what it says, and as we shall hereafter show, seeking to distort its meaning. They ask the court for an injunction to restrain the Board of Directors from acting in accordance with the mandate of the special constitutional provision and challenge the status of the large number of Fellows and Members who have been transferred under it.

POINT I.

The meaning of the special section is very plain to those who read and common sense legal precepts protect it from being obscured or perverted by doses of immaterial legal nostrums.

We quote again the Special Section of the constitution which is under review:

" SPECIAL SECTION: Any person who " shall be a Member at the time this " group of amendments is adopted, " shall, on written request to the Sec- " retary prior to May 1, 1913, with- " out the payment of the transfer fee, " or increase of life membership fee, " have the right to become a Fellow, " provided he refers to at least five " Fellows or Members who, upon in- " quiry, shall certify that he meets the " requirements of the grade of Fellow, " as herein defined.

" Any person who shall be an Asso- " ciate at the time this group of amend- " ments is adopted shall, on written " request to the Secretary prior to May " 1, 1913, without the payment of the " transfer fee, or increase of life mem- " bership fee, have the right to become " a Member, provided he refers to four " Fellows or Members who, upon in- " quiry, shall certify that he meets the " requirements of the grade of Member, " as herein defined.

" The dues of Members and Asso- " ciates transferred under the provi- " sions of this special section shall not " be increased until May 1, 1913."

The Section states that the Member or Associate shall " have the right " to become a Fellow or Member respectively, provided he does two things viz., (1) files a written request with the Secretary and (2), refers to a specified number of Fellows or Members who shall certify on inquiry that he meets the qualifications.

When he does those two things he has, under the constitution, a right to become transferred to a higher grade. How can the Board of Directors in the face of that constitutional provision impose upon the applicant for transfer, additional requirements? When the applicant has complied with the requirements of the constitution which give him the right to transfer he becomes vested with such right and any further requirements by the Board of Directors would be a clear infringement of the constitutional rights of the applicant. The Board of Directors are of course not superior to, but governed by the constitution. When the constitution provides that a Member shall *have a right* upon doing *two* specified

things the Board of Directors have no right to enlarge the requirements and provide an additional requisite so as to compel a Member seeking to exercise his right to do *three things* instead of *two* things.

The language of the provisions is so plain and free from obscurity that it seems almost as uncalled for to invoke legal principles of interpretation as it would be to administer physic where there is no disease. Respect for the high ability and the good faith of those who differ with us admonishes us, however, to give the matter patient treatment.

It is argued on behalf of the plaintiffs that under the general plan embodied in the constitution for the admission and transfer of the various grades of Members there were provided five requisites, viz., (1) the application; (2) references to Members of the Institute; (3) the passing of an examination by the Board of Examiners as to qualifications; (4) election or transfer by vote of the Directors; and (5) payment of the entrance or transfer fees; that the special provision does not expressly abrogate or amend any of those five steps excepting payment of the transfer fee, and modification as to references; that in construing a constitution all of its provisions should, if possible, be given effect, and that therefore it follows that the Special Section does not abrogate or modify any of the five steps above referred to excepting the one requiring the payment of transfer fee, and the modification as to references, and that the other three steps, viz., (1) the application; (3) the passing of the examination by the Board of Examiners and (4) election by the Board of Directors, apply with full force and effect to transfers made under the Special Section.

The particular grievance set up by the plaintiffs is that the Board of Directors have not required the Board of Examiners to pass upon the qualifications of Associates or Members applying for transfer under the Special Section, which under the line of reasoning above set forth it is claimed they were obliged to do.

A ready and it seems to us, an entirely sufficient answer to the argument is that the constitution provides a general rule of procedure for admissions and transfers generally, and then in the Special Section provides for an exception to the general rule.

Where there is a specific matter in mind, and it is dealt with by special reference, it is apparent that the specific expressions as to the particular matter indicate the intention of the author of the instrument. And, so in construing documents it is a familiar rule of law that controlling effect will be given to special provisions over general provisions. The common sense rule applicable to this particular case has been so well, and authoritatively expressed by controlling adjudication that we do not deem it necessary or justifiable to burden the court with a long display of authorities.

The highest court of this state in Wormser *v.* Brown, 149 N. Y. 170 says:—

" When a statute contains separate
" provisions, one special and the other
" general, the latter will not be con-
" strued as including the former, but
" the special statute will be regarded
" as in the nature of an exception to
" the general one. (Hoey *v.* Gilroy, 129
" N. Y. 132; City of Poughkeepsie *v.*
" Quintard, 136 N. Y. 275, 280.)"

In People *v.* Industrial Benefit Assn., 92 Hun, 316, (affirmed 149 N. Y. 606) the Court says:—

" Assuming, as I think we must, that
" by article 6 there was a manifest in-
" tention to limit that business (co-
" operative or assessment insurance)
" to a particular method and scope, the
" general provisions of section 55, if
" applied to such corporations, would
" extend their scope, and so far would
" be inconsistent with and override

" the particular provisions of article 6. " A case is, therefore, presented for the " application of the general rule relative to the construction of statutes, " that when a general intention is " expressed, and also a particular intention incompatible with the general " intention, the particular intention is " to be considered in the nature of an " exception. (Hoey *v.* Gilroy, 129 N. " Y. 132, 138; Potter's Dwarris on " Statutes, 273; Sedg. on Stat. Const. " (2d ed). 361; 23 Am. & Eng. Ency. " of Law, 426; Pretty *v.* Solly, 26 Beav. " 610). In the case last cited it is said: " 'The rule is that, wherever there is a " 'particular enactment and a general " 'enactment in the same statute, and " ' the latter, taken in its most comprehensive sense, would overrule the " ' former, the particular enactment " ' must be operative, and the general " ' enactment must be taken to affect " ' only the other parts of the statute " ' to which it may properly apply.' " Applying this doctrine the general " provision in section 55 would not be " deemed to extend the scope of " article 6."

If it had been intended to give to the special provision the effect contended for by the plaintiffs, it would have been very easy to express it. In such event the section instead of reading as it does now, would have been framed as follows:—

" SPECIAL SECTION. Any person who " shall be a Member or Associate at " the time this group of amendments is " adopted who shall apply for transfer " prior to May 1st, 1913 to the grade of " Fellow or Member respectively, shall " be exempt from the payment of the " transfer fee or increase of life membership fee."

There would have been no purpose in making any provision for references to Members as to qualifications since under the plaintiffs' contention that phase of the requirements for transfer is dealt with in the general provisions which require such references and also require examination as to qualifications by the Board of Examiners.

POINT II.

The fallacy of plaintiff's interpretation is exposed by the grotesque and impossible results that would flow from its adoption.

Let it be borne in mind that prior to the adoption of the amendments which included the Special Section there was no possibility of any Fellow of the Institute being in existence since there was no such grade of Membership.

Let it also be particularly noted that at the time of the adoption of the Special Section the following general provision of the amended constitution became effective, viz., " ALL MEMBERS OF THE BOARD OF EXAMINERS SHALL BE FELLOWS OF THE INSTITUTE," (See Constitution, Sec. 46, moving papers, Fol. 130).

Now the contention of the plaintiffs is that the general provision of the constitution requiring applicants for transfer to have their qualifications passed upon by the Board of Examiners of which the requirement we have just quoted is a part, applies to transfers under the Special Section. That leads our minds to revert to the old conundrum of whether the first egg was laid by a hen or the first hen was hatched from an egg.

There was not, and ever had been in existence, a single Fellow, and yet, it is seriously urged by the plaintiffs that in order to create Fellows. it was necessary to have their qualifications passed on by a committee consisting of five Fellows. Will the plaintiffs kindly advise the court where the Fellows who would constitute that Board of Examiners would come from. The conundrum that confronts them is as follows:

No Fellow can be hatched unless five Fellows set on a Member.

There are no Fellows who can do the

setting, since no Fellow is or ever has been in existence.

Query: How can a Fellow be hatched?

And so, under the plaintiffs' contention we would have the extraordinary result that this body of learned men after four years of careful deliberation and the dissemination of explanatory literature to the thousands of its Members and the elaborate framing of constitutional provisions directed towards the creation of the new and highest grade of Fellow and the transfers of Members from one grade to the other, went through those protracted formalities and that long travail, with the result that no Fellow could ever in fact be created; that no Associate could ever in fact be transferred to the grade of Member; that no Member could be transferred to the grade of Fellow; that not a single Associate, Member or Fellow could ever be elected (since all admissions are provided to be passed on by the Board of Examiners) that all their proceedings were a farce; that the words were meaningless, and that the "grave and reverend signors," the representatives of a great learned body, had struck at the vitals of their Institute in perpetrating upon the Membership a hoax that was on the level of a children's April fool joke. Either that or else this learned body deliberately provided for its gradual extinction. It could not multiply but voluntarily placed itself in the class of two ancient men at Fyzabad, described by Macaulay as "belonging to that unhappy class which a practice of immemorial antiquity in the East has excluded from the pleasures of love and from the hope of posterity."

While of those who proposed and of those who adopted the amendments, it cannot be said that a day was to them as a thousand years, and a thousand years as a day, nevertheless, it is inconceivable that they could fail to realize and contemplate that in a very short span of years under the plaintiff's theory the magnificent building, the library, lecture rooms, the publication of proceedings and the property and entire organization of the Institute would be for the gratification of a sole venerable survivor, and after that for whom? And this disastrous and total wreck would be accomplished by the plaintiffs in the name of the legal maxim that where there is an apparent inconsistency between different paragraphs of an instrument, such construction should be given as will give each provision "a reasonable meaning, force and effect."

We have no quarrel with that wholesome and sensible rule which however, it is entirely unnecessary to cite since there is no real or apparent inconsistency in the case under discussion.

Assuming, however, that the rule is germane, then the plaintiffs are at fault in not applying it. If they did apply it, it would be fatal to their claims. In the name of a rule that provisions of a constitution be given a "reasonable meaning" they ask for an interpretation which gives them no meaning. In the name of a rule that constitutional provisions be given "*reasonable force and effect*," they ask for an interpretation that would destroy them. They proclaim light and produce darkness. They offer bread and present a stone. They cry out aloud that life must be saved and straightway prescribe a deadly poison.

As against the impossible conditions following the plaintiffs' interpretation, we have the workable conditions flowing from the plain language of the Special Section. There being no Fellows in existence at the time, what did the Special Section provide? It gave a Member the absolute right to become a Fellow upon filing his request and referring "to at least five Fellows *or Members*." It was realized that when the Special Section became effective there would be no Fellows and hence any then Members might have themselves transferred to the rank of Fellows by filing their application and by the filing by five Members of their requisite certificates and thus the amended constitution

would be a workable one, both in respect to the Special Section and the general provision.

POINT III.

Even though for the sake of argument it should be assumed that the general provisions of the constitution apply to the special section, the Board of Examiners would, nevertheless, not be required to pass upon applications under the special section, nor would they have any authority to do so.

Let it be observed that the Special Section is embraced in Article *II.* of the constitution (moving papers, Fol. 102), whereas the general provisions relating to admission and transfer of Members are contained in Article *III.* of the constitution, (moving papers, Fol. 105).

The only powers of the Board of Examiners are those set forth in Section 53 of the constitution reading as follows:

" 53. The Board of Examiners shall " pass upon the qualifications of all " applicants for election or for transfer, " whose applications have been received " by the Secretary *and which are in* " *conformity with Sections* 10, 11 *and* 12 " *of Article III.* and it shall report its " findings to the Board of Directors for " action."

Thus, there is no power in the Board of Examiners to examine into the qualifications of applications for transfer made under the Special Section, since such applications are made under Article II, Section 7, and not under Article III, Sections 10, 11 and 12.

There is a difference in the applications under the Special Section and under Article III. Thus, under the Special Section an applicant for transfer from Member to Fellow may refer to either five Fellows or five Members, whereas, under Article III he is required to refer to five Fellows; besides the forms of references and certifications are essentially different in the two Articles. Thus, under Article III the applicants are simply required to give references to Members of the Institute, whereas, under the Special Section the persons referred to are upon inquiry required to certify that the applicants possess the requisite qualifications.

It will thus be observed that the forms of procedure are different and manifestly distinct. Right here is sharply brought out the difference in the general procedure and the special procedure. Thus, under the Special Section an applicant refers to other Members who in turn are required to certify as to his qualifications while under the general provisions in Article III. the applicant merely refers to Members and the Board of Examiners thereupon examine into his qualifications and they in effect act as his certifiers.

But the plaintiffs may seek to escape from these observations, by claiming that a member applying under the Special Section was obliged to apply also under the general provision, in other words, to make two applications. The contention is obviously strained. It would require duplication of applications, manifestly a purposeless procedure and it would require a duplication of inquiry into qualifications, one by the certifiers and the other by the Board of Examiners. Furthermore, it would be discriminating against the then existing Members and imposing upon them greater burdens than those demanded of strangers applying for the grades which they were seeking. And a further and conclusive answer to any such unreasonable contention is the fact that under Article III. one applying for the grade of Fellow is required to refer to five Fellows and if it were necessary to apply under that article in order to become a Fellow, then no Fellow could ever be created since there was no Fellow in existence to whom reference could be made.

POINT IV.

Under the plaintiff's interpretation all the elaborate labor for the operation

of the special section would have had for its objective point the achievement of something so trivial as to make it unreasonable to attribute it to a learned body having the standing of the American Institute of Electrical Engineers.

As above shown the argument of the plaintiffs is that the only effect of the section was to relieve the applicant for transfer from the payment of transfer fee, and life membership fee. The affidavit of the Secretary shows that life memberships are very slightly availed of and it appears that of a membership of over 7,000 there were only forty-five (45) life memberships in the Institute on May 21st, 1912, and that there have only been five (5) life memberships taken out since that date. Thus, the life membership feature could not have been a substantial moving cause for the amendment.

By reference to the constitution (moving papers, Fol. 112), it will be noted that the transfer fee was but five dollars, so that on the plaintiff's theory it would come to this, that the elaborate procedure under the special section had for its substantial purpose the saving of a transfer fee of five dollars.

POINT V.

The view and expressions while the amendment was under consideration accord with the view taken by the Board of Directors and show that the claims of the plaintiffs are hostile to the real understanding and intent of those who framed and those who voted for the amendment in question.

The considerations leading to the adoption of the Special Section are set forth in the affidavit of Mr. Gano Dunn who was President during the year of their adoption and they conform to the opinion of the Board of Directors and to the views set forth in the statement at the head of this brief.

These views are confirmed by all of the Directors during the year ending August, 1912, who were not absent and inaccessible in the limited time we had for presenting affidavits upon the motion, viz., Messrs. Severn D. Sprong, Howel H. Barnes, Jr., Farley Osgood, Walter S. Rugg, George A. Hamilton, and Williard G. Carlton. But as a contemporary expression of the purposes and meaning of the Special Section we have the statement issued by Mr. Dunn the President of the Institute the statement being published in February, 1912, in the official organ of the Institute which was mailed to every Member of each grade and being again published in pamphlet form in March, 1912, and again mailed to each Member of each grade of the Institute with the ballot on the porposed amendment. In that statement the President explained the proposed amendment in the following language:—

"*It will be seen that in the case of*
"*those who are already Members at the*
"*time the amendments are adopted, the*
"*transfer to the grade of Fellow does not*
"*go through the Board of Examiners in*
"*the usual form of routine. The labor*
"*of passing upon such transfers as*
"*would take place in connection with*
"*passing the large numbers of existing*
"*Members over into the grade of Fellow*
"*would be more than the Board of Exam-*
"*iners or, in fact, any other committee*
"*of the Institute could undertake. In*
"*the Amendments it is left to five of a*
"*Member's friends in the society, who,*
"*by certifying to the facts of his exper-*
"*ience, act as a Board of Examiners.*"

POINT VI.

The practice under the special section is in exact accord with the requirements of the special section.

The procedure is set forth in Mr Dunn's affidavit at folio 16.

"An Associate or Member desiring
"to be transferred under such special
"section has filed his application with
"the Secretary giving the names of
"those Members or Fellows who are

"to certify him under the provisions "of the special section. Thereupon, an "inquiry has been sent to the persons "designated by the Associate or Mem- "ber seeking transfer in forms which "are hereto annexed marked 'B' and "'C' entitled 'Transfer reference form "under special section of constitution "and by-laws,' Exhibit 'B' being sent "in cases of requests for transfer from "Associate to that of Member and "Exhibit 'C' in cases of requests of "transfer from the grade of Member to "that of Fellow.

"The form of said inquiry has been "the same as Exhibit 'B' and Exhibit "'C' throughout, excepting that in "the earlier forms the form of certificate "has not included a statement that "the certifier has read the requirements "for transfer. Thereafter, upon the "receipt of the requisite number of "certificates as required by the special "section the Secretary down to January "of this year, reported the facts in the "matter to the Board of Directors who "have thereupon directed the transfer "to be made in accordance with the "provisions of said special section.

"At a meeting of the Board of Direct- "ors held on December 13th, 1912, the "Board passed the following resolution:

"'RESOLVED, that all applications "'and their certifications hereafter "'received by the Secretary for "'transfer from one grade of mem- "'bership to another, under the "'special section of the Constitution, "'be referred by the Secretary to the "'Board of Examiners to check as "'to the accuracy of the facts which "'it is understood do not include "'questions of professional standing "'certified to under the provisions of "'the Special Section of the Con- "'stitution.

"'RESOLVED, that the Board of "'Directors hereby adopts, and will "'be governed by, that interpreta- "'tion of the Constitution which "'construes that transfer by the "'Board of Directors of duly certi- "'fied applicants is obligatory.'"

"The Board of Examiners refused "to act under the limitations prescribed "by said resolution and thereupon at "the Board meeting on January 10th, "the following resolution was adopted:

"'RESOLVED, that the resolutions "'in relation to the reference of "'names of applicants for transfer "'under the Special Section to the "'Board of Examiners passed at "'the Directors' meetings of Novem- "'ber 8th and December 13th be "'rescinded and

"'RESOLVED, that all applications "'and their certifications now pend- "'ing and hereafter received by the "'Secretary for transfer from one "'grade of membership to another, "'under the Special Section of the "'Constitution, be referred by the "'Secretary to a special committee "'consisting of the Secretary and "'three members of the Board of "'Directors, to be appointed by the "'President, to check as to the ac- "'curacy of the facts, which it is "'understood do not include ques- "'tions of professional standing, "'certified to under the provisions "'of the Special Section of the Con- "'stitution, and

"'RESOLVED, that the Board of "'Directors hereby adopts, and will "'be governed by, that interpreta- "'tion of the Constitution which "'construes that transfer by the "'Board of duly certified applicants "'is obligatory.'"

"Since the adoption of said resolu- "tion applications and certificates for "transfer under the Special Section "have been examined by said special "committee consisting of the Secretary "and three members of the Board who "have been appointed for that purpose, "and they have reported to the Board "and thereupon the Board has directed "the transfers under such section."

POINT VII.

The application for an injunction should be denied with costs.

Respectfully submitted,

PARKER & AARON,
Attorneys for defendant,
American Institute of Electrical Engineers.

HERMAN AARON,
Counsel.

Kelvin Memorial Dedication

Notice has been received at Institute headquarters from London that July 15 has been decided upon as the date of the dedication of the Kelvin Memorial Window. The proposal to honor the memory of Lord Kelvin by the erection of a memorial window in Westminster Abbey originated with the Institution of Civil Engineers of Great Britain early in 1912, and in order that the tribute could be world-wide, it was determined to present the opportunity to contribute to the engineers of the United States as well as those of the United Kingdom. Accordingly, various national engineering societies in this country, including the American Institute of Electrical Engineers, of which Lord Kelvin was for many years an Honorary Member, were invited to cooperate. The representatives of the Institute upon the General Committee issued a circular letter to the membership in August, 1912, in response to which contributions were received from 190 members. The total number of contributors to the general fund exceeded 1300, and the entire amount required to carry out the undertaking has been received.

Members of the Institute who expect to be in London on July 15, are invited to attend the ceremonies, and are requested to communicate with Dr. J. H. T. Tudsbery, Honorary Secretary and Treasurer, Kelvin Memorial Fund, at the office of the Institution of Civil Engineers, of which he is Secretary, at 12 Dartmouth Street, Westminster, S.W. In each case the member should send to Dr. Tudsbery the London address to which particulars of the arrangements may be forwarded.

Members who expect to visit London either at the time specified or later, and who desire to avail themselves of the visiting member privileges established last year by the governing bodies of the Institute and the Institution of Electrical Engineers, of London, will be furnished with the proper credentials upon application to the Secretary, at Institute headquarters, 33 West 39th Street, New York.

Past Section Meetings

BALTIMORE

The April meeting of the Baltimore Section was held in the Physical Laboratory of the Johns Hopkins University on Friday evening, April 25. The chairman, Dr. J. B. Whitehead, presided, and the attendance was 30.

Mr. Clarence Renshaw, railway engineer of the Westinghouse Electric and Manufacturing Company, gave a paper entitled "Notes and Comments on Electric Traction." The paper was followed by a discussion.

BOSTON

There was a meeting of the Boston Section of the American Institute of Electrical Engineers in the auditorium of the Edison Building, 39 Boylston Street, Boston, on Friday evening, May 23. Chairman F. P. Valentine presided.

The Boston Society of Civil Engineers and the American Society of Mechanical Engineers were both invited to this meeting, as the paper presented was one which would interest any member of the engineering profession.

Mr. Roy M. Henderson, assistant construction manager of the Stone and Webster Engineering Corporation, presented a paper entitled "The Organization and Methods of a Large Engineering and Construction Company (with special reference to the Stone and Webster Engineering Corporation)."

There was an attendance of over two hundred.

At the business meeting of the Section

the nominating committee made its report, and the following officers were elected for the coming year: chairman, N. J. Neall; vice-chairman, Harold Pender; secretary, L. L. Edgar; executive committee, F. M. Gunby, G. K. Manson and E. L. Moreland.

Detroit—Ann Arbor

A meeting of the Detroit-Ann Arbor Section was held on April 26, in Detroit. The presiding officer was Mr. S. C. Dinsmore, and the attendance was 25.

Professor A. R. Sawyer, of the department of electrical engineering of the Michigan Agricultural College, introduced Mr. Arthur A. Meyer of the Detroit Edison Company, who made an address on "The Improvement of the Power Factor of Central Stations." This was followed by a general discussion by the members and visitors.

Mexico

The regular meeting of the Mexico Section was held at the Restaurant Gambrinus on Thursday evening, May 8. Chairman H. S. Foley presided, and the attendance was 34.

Mr. Harvey Diamond, general agent of the Central Mexico Light and Power Company, presented a paper on "Electricity and Agriculture." Mr. Diamond has had a wide experience in applying electrical power for farm and general irrigation purposes in the Republic of Mexico, and described some of the difficulties met with in this work. He outlined the usual practise in putting down wells for small farms of ten to twenty acres. The big strawberry fields of Irapuato and Leon and the farms of Puebla are now showing the results of the systematic efforts of the electrical engineers in teaching Mexican farmers the advantages of irrigation by electrical pumping.

Mr. W. H. Fiske was appointed as the delegate of the Mexico Section to the Annual Convention of the Institute.

Milwaukee

The regular joint meeting of the Milwaukee Section of the A. I. E. E. and the Engineers' Society of Milwaukee was held May 14 at the Plankinton House. Mr. F. T. Dodd, of the railway engineering department of the General Electric Company, Schenectady, presented a paper on "The Gas-Electric Car." As an introduction, he described the various types of cars used at present for the transportation of passengers, pointing out the field of the electric car getting its power from an external source, of the gasoline-driven car, of the storage battery electric car, and of the gas-electric car.

Mr. Dodd then gave a detailed description of the gas-electric car as built at present by his company. He showed the construction of the car by means of slides, and then took up the detailed construction of the power and controlling plant. The gasoline engine generator set was described; special stress was laid on the method of starting the engine, the method of oiling the engine and the method of mixing the gas and air. The interpole generator and the controller were then described in detail. The striking feature of the controller was said to be its extreme simplicity of operation. Attention was called to the interpole railway motors on trucks, and also to the special construction of the trucks. A discussion followed, in which further points were brought out in regard to cost of operation.

Chairman T. E. Barnum presided, and 100 members and visitors attended the meeting.

Pittsburgh

A meeting of the Pittsburgh Section was held on May 13, in the rooms of the Engineers' Society of Western Pennsylvania. Chairman E. L. Farrar presided, and the total attendance was 50.

Mr. C. E. Skinner, of the Westinghouse Electric and Manufacturing Company, past chairman of the Section, spoke on the subject of the Panama Canal, and other foreign ports. The lecture was well illustrated with lantern

slides. Mr. Skinner discussed the construction of the canal, mentioning some of its more important engineering features.

It was decided to devote the June meeting to safety appliances for transportation, and to have Mr. Guy P. Thurber present a paper.

PITTSFIELD

The Pittsfield Section has held the election of officers for the year 1913–14, their term of office beginning August 1, 1913, with the following results: chairman, J. J. Frank; vice-chairman, W. W. Lewis; secretary-treasurer, G. W. Wade; member at large of executive committee, for two years, E. T. Shaw. Mr. S. E. Johannesen holds over for one year as member at large of the executive committee.

PORTLAND, ORE.

The Annual Meeting of the Portland Section was held at the Hotel Oregon, Tuesday evening, May 20. Chairman H. R. Wakeman presided, and the total attendance was 37.

The business session was preceded by a dinner, during which a varied entertainment was provided, consisting of instrumental and vocal music, and specialties by several members.

The election of officers for the ensuing year took place immediately after the dinner. Those elected were: chairman, G. P. Nock; secretary-treasurer, R. F. Monges; executive committee, W. D. Scott, H. R. Wakeman and C. E. Condit.

The chairman announced that Mr. H. M. Friendly would be the official delegate of the Section to the Annual Convention at Cooperstown. Brief talks were made by the chairman, the chairman-elect, and several other members.

After enjoying more music, the meeting adjourned to meet again in October.

ST. LOUIS

The May meeting of the St. Louis Section followed a dinner in one of the private dining rooms of the American Hotel, on May 14. Chairman Joseph A. Osborn presided, and twenty members were present.

Annual reports of various committees were received. The following officers were elected for the year beginning August 1, 1913: F. J. Bullivant, chairman; A. McR. Harrelson, secretary; S. N. Clarkson, member of executive committee. These three, together with Messrs. Joseph A. Osborn and Charles A. Hebein, elected last year, constitute the executive committee for the year beginning August 1, 1913.

SEATTLE

The Seattle Section held a meeting on May 20, in the assembly hall of the Chamber of Commerce. Chairman J. D. Ross presided, and 35 members and visitors were present.

The Section voted to make an inspection trip to the Nisqually power plant of the city of Tacoma, on June 17, to take the place of the June meeting, and to be the last of the Section's activities for the season, until September.

Chairman Ross appointed Messrs. Terrell and Dunbar as additional members of the membership committee. Mr. M. T. Crawford, secretary of the Section, was appointed as delegate to the Annual Convention at Cooperstown. A resolution was passed expressing the approval by the Section of the plan to allow each Section two delegates to the annual conventions.

Four ten-minute papers were then presented, as follows: "Notes on Transmission Construction," by Mr. M. T. Crawford; "Substation Construction," by Mr. C. F. Terrell; "Alternating-Current Distribution," by Mr. F. C. Nelson; and "Direct-Current Distribution," by Mr. C. R. Collins. The first two papers were illustrated by some 80 photographs and lantern slides showing transmission and substation construction practise on the Pacific Coast. The papers were discussed by Messrs. Harisberger, Robinson, Dunbar, Ross, Miller, Lindsay and others.

Vancouver

A business meeting of the Vancouver Section was held at the University Club on May 2, 18 members being present. In the absence of Chairman Nims, Secretary E. M. Breed presided. The secretary announced the personnel of the general convention committee and local sub-committees entrusted with the work of preparing for the Pacific Coast Convention of the Institute to be held in Vancouver, September 9–11, 1913. These committees have already been announced in the April and June Proceedings.

Mr. R. F. Hayward, chairman of the convention committee, then outlined in a general way the work that had been done and the plans for the convention. Suggestions were made by members present, and a general discussion of the work followed.

The Section then unanimously elected, for the year 1913–14, the officers who had been nominated at the meeting on April 4. The new officers are: chairman, E. M. Breed; secretary, L. G. Robinson; executive committee, F. D. Nims, W. V. Hunt and G. R. Wright.

In accordance with the plans approved at the preceding meeting, the chairman-elect named Messrs. T. R. Cornick, W. McNeil, W. H. R. Fraser, J. R. Read, G. R. Wright, F. D. Nims, John Montgomery, E. P. LaBelle, L. G. Robinson and K. A. Auty to prepare papers for discussion during the coming season.

Washington, D. C.

The May meeting of the Washington Section was held at the Telephone Building on May 13. This was the last meeting of the season and the Annual Meeting, as well. Chairman J. H. Finney presided, and the total attendance was about 125.

The secretary's annual report showed a small average attendance for the year of Institute members, while the attendance of local members was proportionately large. The report also showed a substantial balance in the treasury.

The following officers were elected for the year 1913–14: chairman, H. C. Eddy; secretary, C. B. Mirick; executive committee, R. H. Dalgleish, C. A. Petersen and A. Dunlop. Alternates to Convention, H. C. Eddy and A. Dunlop.

At the close of the business session, Mr. Guy P. Thurber, president of the Gray-Thurber Signal Company, delivered an illustrated lecture on the subject "Automatic Train Control." The speaker gave an interesting and detailed description of the construction and operation of the Gray-Thurber automatic train stop as applied to both steam locomotives and interurban electric cars.

At the close of the meeting refreshments were served and a social time was enjoyed.

Past Branch Meetings

University of Arkansas

The University of Arkansas Branch on May 14 had a banquet which it was decided to make an annual affair hereafter. The senior drawing room had been decorated for the occasion. In addition to addresses by three of the professors, each member of the Branch was called on for a brief talk. The addresses were as follows: "The Electrical Engineer of the Future," Professor W. N. Gladson; "Side Lights," Professor G. E. Ripley; "Our Engineering Societies," Professor W. B. Stelzner.

Armour Institute of Technology

The Armour Institute of Technology Branch gave a banquet and held a short business meeting on April 26. At the close of the dinner the meeting was addressed informally by several of those present. Officers for the coming year were elected, as follows: chairman, E. L. Nelson; secretary, T. C. Bolton; treasurer, A. F. Schoembs.

A meeting of the Branch was held on May 15, when Mr. Eugene Lang read a paper on "The Gas-Electric Car." Mr. Lang explained in detail the construction and operation of railway cars of this type and showed under

what conditions they could be recommended for use.

Bucknell University

The Bucknell University Branch held a meeting on May 2. The speaker was Mr. H. S. Sweet, 1911, who has been in the employ of the General Electric Company during the past year. Mr. Sweet gave a talk on the methods of testing used by the company and the kind of work done by student apprentices.

A meeting of the Branch was held on May 15, when Mr. Harry Bliss read and discussed a paper on "Patents." He discussed the methods used in making application for a patent, and gave examples of lawsuits that had arisen from interferences.

Clemson Agricultural College

The last meeting of the Clemson Agricultural College Branch for 1912–1913 was held on May 12. The following papers were presented: "Thermit and Its Uses," Mr. D. M. Sloan; "Electricity in the United States Navy," Mr. J. H. Kangeter; "The Gyroscope as Applied to Navigation," Professor F. R. Sweeny. A review of recent issues of the *Electrical World* was contributed by Mr. F. H. McDonald.

The Clemson College Branch was organized last November and its first year of activity has been a very successful one. Most of the electrical engineering students are members of the Branch, and every effort has been made to make the organization a large factor in the development of its members.

University of Colorado

The University of Colorado Branch held a meeting on May 14 for the election of officers for the coming year. The results were as follows: president, Leonard E. Sweitzer; vice-president, Clinton F. McKelvey; secretary, Frank A. Redding; treasurer, Charles R. Lynch; junior representative, Thornton M. Victory.

University of Kansas

The final meeting of the University of Kansas Branch was held on May 21. Messrs. H. D. Hoadley and J. E. Turkington gave talks on their thesis work. Mr. M. K. Thoman, 1912, gave a talk on his work with the Empire Electric Company of Joplin, Mo.

Officers for the coming year were elected as follows: chairman, H. C. Hansen; vice-chairman, G. A. Washburn; secretary-treasurer, L. M. Bocker; executive committee, Professor G. C. Shaad and Messrs. A. J. Fecht, R. V. Lentz, and K. W. Wright.

Lafayette College

The Lafayette College Branch held a meeting on May 20, when the following papers were presented: "Tests on Flicker Photometer and Ulbricht Sphere," Messrs. George Heydt and Edwin Fager, and "The Principle which Determines the Direction of Rotation of Direct-Current Machines," Mr. William Thompson.

University of Missouri

The University of Missouri Branch met on April 14, when a general discussion on "The Choice of Work for Graduating Engineers" was led by Messrs. R. E. Powell and S. M. Hardaway. Others who discussed the subject were Messrs. Gmeiner, Fountain, Armstrong, Brady, Spurgeon, Woodson, Towles, Langford, McClain, and Kellogg. Several men quoted letters from former graduates about the work they were engaged in.

A meeting of the Branch was held on April 28, when an address was delivered by Dr. Isidor Loeb on "The Necessity of Constitutional Revision in Missouri."

The next meeting of the Branch was held on May 12, when Professor T. J. Rodhouse gave a talk on "The Drainage of the Florida Everglades." Professor Rodhouse outlined the climatic and geologic conditions in the Everglades and the great difficulty of drain-

ing this immense area of land, which is really a wet prairie of sand and muck of little depth overlying a limestone reef. About 2160 square miles are regarded as drainable, and about an equal amount at the lower end is not drainable. Drainage plans involve digging a number of large canals across the Everglades to the ocean, to intercept the overflow from Lake Okeechobee as well as to carry off the surplus water from the Everglades. The present plans involve six canals 20 ft. deep and 75 ft. wide, but it is thought they will need to be much larger than this.

The last meeting of the Branch for the year was held on May 26, when officers were elected for the coming season, as follows: vice-chairman, L. E. Knapp; secretary, E. W. Kellogg; assistant secretary, R. G. Thompson; treasurer, E. V. Gmeiner. The election of chairman and executive committee was postponed until the first meeting in the fall. After the business meeting had been concluded Professor L. M. Defoe gave an informal talk to the Branch.

Montana State College

At the regular meeting of the Montana State College Branch on April 17, President J. M. Hamilton made an address on the subject of "The Economics of Engineering." The importance of taking into consideration the application of the general laws of economics, as well as the strictly technical side of any enterprise, was emphasized. This is often overlooked by engineers and investors. President Hamilton said that during his long residence in Montana as an educator he had seen many failures resulting from this inability to take into proper account the various conditions met with in a new country. He called attention to many specific instances of deserted mines, mills, dairies, and smelters which stand as monuments to failures of this kind. With so many engineering projects being promoted, and the opportunities offered for an even greater number, there is a tendency for students and engineers to see only the technical phases and to neglect those wider considerations which are of even greater importance.

Mr. R. J. Cobban, of the Westinghouse Electric and Manufacturing Company, delivered an address before a special meeting of the Branch on April 23, dealing with the student apprentice course of his company. Mr. Cobban explained, with the aid of stereopticon views, the character of the work and the life at Pittsburgh, and the opportunities offered for obtaining a great deal of valuable information and experience.

Ohio Northern University

The Ohio Northern University Branch met on the evening of April 23. Mr. C. Buezis gave a talk on "Industrial Lighting;" Mr. L. F. Doty, a talk on "Comparative Types of Transformers;" Mr. Leslie A. Peck, a paper on "Central Station Power for Coal Mines" and "Electricity in the Mines;" and Mr. R. H. Hart, a talk from practical experience on "Telephone Engineering."

On the evening of May 7 the Branch heard an address by the secretary of the Cleveland Section, Mr. R. B. Chillas, Jr., a chemical and electrical engineer of the National Carbon Company. His lecture, "The Manufacture of Artificial Carbon Products," was illustrated with stereopticon views of the machinery, the buildings and the products of his company.

Ninety-seven engineering students were present.

The final meeting of the Ohio Northern University Branch was held on May 21. The following talks were given by members: "Waste Heat Plant," by T. M. Freeman; "Typical Motor Construction," by Pearl Penquite; and "The Telephone and Its Present-Day Applications," by K. B. McEachron.

The election of officers for the coming year was then held, Mr. George A. Boesger being elected chairman, and Mr. Harry Restofski secretary.

OREGON AGRICULTURAL COLLEGE

A meeting of the Branch was held on April 22. Professor Hillebrand gave an illustrated lecture on " Power Plant and Line Construction." The slides were shown by Mr. H. V. Morton of the Oregon Power Company, who collected them from various sections of the United States. There were 41 members and visitors present.

A meeting of the Oregon Agricultural College Branch was held on May 21. Mr. Lebenbaum, of the Portland, Eugene and Eastern Railway, gave a lecture on the electrification of that line. A general discussion of the electrification of railroads followed.

RENSSELAER POLYTECHNIC INSTITUTE

The regular May meeting of the Rensselaer Polytechnic Institute Branch was replaced by an inspection trip to the Adirondack Water Power Company's hydroelectric plant and the Delaware and Hudson Railway Company's steam plant at Mechanicville, N. Y. on May 10.

RHODE ISLAND STATE COLLEGE

On May 8 the regular monthly meeting of the Rhode Island State College Branch was held. The members listened to a talk by Professor Dickinson of the electrical engineering department, who spoke on " The Application of Thermocouples to Measurements of Temperature in Electrical Machines." After this address the officers for the ensuing college year were elected, Mr. Harry Webb being re-elected as chairman; Mr. L. A. Whittaker vice-chairman; Mr. W. C. Miller as treasurer; and Mr. P. M. Randall as secretary.

The next regular meeting will be held in June, when it is planned to invite the Agricultural Club of the college to listen to a paper on " Applications of Electricity to the Farm, " to be presented by Mr. L. A. Whittaker.

ROSE POLYTECHNIC INSTITUTE

In place of the customary meeting of the Rose Polytechnic Institute Branch on March 27, members and visitors made a tour of inspection through the Citizens' Telephone Company's exchange in Terre Haute. Mr. A. L. Stadermann, engineer of the company, acted as guide and explained points of interest to the party.

STANFORD UNIVERSITY

A meeting of the Stanford University Branch was held on April 24. Nominations were made for officers for the coming year, the election to take place at the next meeting. Committees were appointed to arrange for the semester banquet on May 6, and to arrange for a concession at the " Senior Carnival " and the giving of an entertainment by the Branch.

Short talks were then given by Messrs. Calderwood and Wright. The latter described his experiences in the Stanislaus hydroelectric plant, and Mr. Calderwood reviewed some cases of trouble occurring on the lighting system in Palo Alto.

The semester banquet of the Stanford University Branch was held on May 6. Chairman L. C. Lull acted as toastmaster. Speeches were made by Mr. C. F. Elwell, 1908, Mr. C. O. Wilson, 1914, and Professor Harris J. Ryan. The guests of the evening were Professors C. D. Max, C. B. Wing, W. F. Durand, D. M. Folsom and Mr. C. F. Elwell. Officers for the coming year were elected as follows: chairman, G. O. Wilson; secretary, L. M. Bussert; librarian, W. Hosting; treasurer, D. L. Erwin.

SYRACUSE UNIVERSITY

At the meeting of the Syracuse University Branch on April 16, Mr. R. W. Grower made an address on " The

Production of High-Frequency Oscillations."

Mr. A. C. Brettle was the speaker at the meeting of the Branch on April 24, his subject being " Electrical Injuries."

A meeting of the Branch was held on April 30, when Mr. C. G. Axtmann spoke on " Railway Signals."

At the meeting of the Branch on May 7 Mr. C. R. Braly presented a paper on " Industrial Lighting."

At the meeting of the Syracuse University Branch on May 14, Mr. T. S. Caldwell presented a paper on " Telephones," and Mr. G. E. Reed spoke on " Electric Automobile Starters."

The next and final meeting of the Branch for the year was held on May 21, when Mr. H. S. Miller outlined and discussed the Standardization Rules of the Institute.

Throughout the present semester the plan of the Syracuse University Branch has been to hold weekly forenoon meetings, the seniors presenting original or Institute papers for discussion. It is expected that this policy will be continued next fall.

University of Texas

The University of Texas Branch held a meeting on March 1, when a paper on " The Development and Economy of Various Incandescent Lamps " was presented by Dr. N. H. Brown.

Mr. Paul Hilker presented a paper on " The Automatic Telephone System " at the meeting of the Branch on April 4.

A meeting of the Branch was held on April 13, when talks on " The Growth, Organization and Activities of The Southwestern Telephone and Telegraph Company " were given by Messrs. Elias and Jensen of the company.

University of Virginia

A meeting of the University of Virginia Branch was held April 21. Mr. Charles Hancock, professor of mechanical engineering, read a paper entitled, " The Development of the Southern Power Company." After giving statistics showing the extent and output of the company, Professor Hancock brought out many interesting points in the operation of the plant, one of which was the shifting of the load from the steam to the hydraulic stations in order to keep down the amount of water wasted at times of floods and light loads. The paper closed with a discussion of the rates charged by the company.

Worcester Polytechnic Institute

The regular monthly meeting of the Worcester Polytechnic Institute Branch was held on April 18. The address of the evening was on " Commercial Testing," by Mr. F. W. Gay, of the Crocker-Wheeler Company. Mr. Gay outlined the direct-current tests as carried out by his company, pointing out the great improvements brought about in electrical apparatus within a few years and also showing just why commercial tests are very necessary.

In closing his talk, Mr. Gay discussed interpole motors, speaking both of the methods of testing and advantages of application.

At the next meeting of the Branch on May 9, three members of the senior class discussed the subjects of their respective theses, as follows: Mr. Anson M. Vibbert, " Tests of an Aluminum Cell Lightning Arrester;" Mr. Albert C. Gowing, " Electric Vehicles, with Reference to Worcester Conditions;" Mr. Arthur C. Burleigh, " The Comparison of High Temperatures by Electrochromatic Methods." The speakers gave interesting abstracts of the work

they have been carrying on, and showed some of the laboratory methods and apparatus employed.

The annual election of officers of the Worcester Polytechnic Institute Branch was held on May 16. Mr. William C. Blanchard, Jr., was elected president, and Mr. Harry B. Lindsay secretary.

YALE UNIVERSITY

A student meeting devoted to the subject of electric heating was held by the Yale Branch on April 9. A paper was read by Mr. M. R. Wibberley, 1913-S, on "Industrial and Domestic Electric Heating," and one by Mr. R. H. Willard, 1913-S, on "Electric Welding and the Electric Furnace." Both papers were illustrated by pictures and samples of apparatus.

A joint meeting of the Yale Branch A. I. E. E. and the Yale Mechanical Engineers Club, a branch of the A. S. M. E., was held on April 23. The speaker, Mr. L. W. Morse, terminal engineer of the Grand Central Terminal, New York, gave a lecture, illustrated by lantern slides, on "Terminal Improvements of the New York Central Railroad." He first showed that what limits the capacity of a railroad line is its terminal facilities; a brief history of the railroad terminals in New York was given, leading up to the building of the present terminal which was begun in 1904. Pictures showed details of the construction work and by what methods traffic was kept up while the work was in progress. The methods of signaling and the precautions for safety were described at some length. The fact was emphasized that the possibility of the existence of such a terminal rested upon the use of electricity for operating trains.

Mr. J. W. Lieb, Jr., general manager of the New York Edison Company, was the speaker at a meeting of the Yale Branch held on May 14. His subject was "Engineering Features of the Dayton Flood." Mr. Lieb went to Dayton during the recent flood in order to assist the electric companies in restoring service, and his talk was, in large part, a description of what he had actually seen and done there. Regarding measures for preventing such a flood, he stated that no amount of preparation and foresight could have had much effect on the consequences, inasmuch as the enormous rainfall—eleven inches in five days—was entirely unprecedented. By means of lantern slides and motion pictures actual conditions of the flood and its results were illustrated. Some features of engineering interest were: the building of boats for navigation in the streets by the National Cash Register Company's men at the rate of one boat every twenty minutes, the repairing of broken iron lamp posts by means of acetyline welding, and cleaning the mud out of electric meters by turning the hose on them.

Mr. Lieb paid tribute to the work of many of the big companies in Dayton for their help in the restoration work after the flood, to many outside companies for sending men and materials, and to the people of Dayton, who were so well organized to carry on the work of relief and restoration.

At the business meeting of the Branch, officers for next year were elected as follows: chairman, R. G. Warner; secretary, K. B. Jones; treasurer, M. G. Carter; governing board (in addition to the above officers), P. B. Vallé, J. R. Weeks, Jr., and Professor C. F. Scott.

A meeting of the Yale Branch was held in Mason Laboratory on the evening of May 21. As this was to be the last meeting of the year, the officers for the coming year were installed.

Mr. Bassett Jones, the speaker of the evening, outlined in his talk the requirements of an illuminating engineer, and he described methods of making cal-

culations for illumination. But for certain material reasons—such, for instance, as the fact that the reflecting powers of substances are not accurately known—and because it is really effect, and not illumination, for which the engineer is working, the results of calculations only give a first approximation to the solution of the problem. The real solution must depend upon experience. Slides were shown illustrating some methods of lighting. One installation, the Soldiers' Memorial in Pittsburgh, was described in detail.

An interesting feature was a demonstration of light effects by means of a "color booth" provided with colored lamps, dimmers, etc. The striking difference caused by light from different angles on architectural designs, and the effects of light of different colors upon colored fabrics, were studied.

Chronology of Aviation

The Secretary has received from Mr. Hudson Maxim and Mr. William J. Hammer a limited number of reprints, just issued, of the very complete "Chronology of Aviation" which they originally prepared for the World's Almanac of 1911. The data embrace the essential facts relating to aerial progress. In addition to a short historical resume, the contents include tables giving altitude records, speed records, quick starting and slow speed records, passenger carrying records, English channel and other over-water flights, cross-country flights, and notable distance and duration flights. There are also statistics relating to accidents and data relative to spherical and dirigible balloons or airships, etc. Of no small interest are the tables giving the most important work of the Wright brothers. There are doubtless many of the members of the Institute who are much interested in this subject and who would be glad to obtain a copy of this interesting brochure. They can do so without charge by applying to the Secretary.

Personal

MR. HARRY WINTHROP TURNER, who for the past twenty-one years has resided abroad, in England and Germany, is now connected with the General Electric Company's research laboratory, Schenectady, N. Y.

MR. A. HUSSEY, who has been since January 1 acting superintendent of distribution for the Edison Electric Illuminating Company of Brooklyn, was appointed superintendent of distribution on April 1.

MR. P. A. MORSE, who has been for many years associated with the Western Electric Company, has gone into business for himself and will sell electrical apparatus. His office is in the Central National Bank Building, St. Louis, Mo.

MR. A. I. M. WINETRAUB, of the foreign department of the General Electric Company, Schenectady, has made arrangements with Messrs. Zaldo and Martinez (formerly Sussdorf, Zaldo and Company) of Havana, whereby he is to act as their sugar machinery engineer in Cuba.

MR. LASZLO DE VEREBELY, formerly with the Westinghouse Electric and Manufacturing Company, and lately connected with the Ganz Electric Company in Budapest, Hungary, has been appointed chief engineer of the Soc. Italiana Westinghouse, Vado-Ligure, near Genoa, Italy.

MR. CHARLES F. GRAY, consulting electrical engineer, Winnipeg, Man., has removed to larger offices at 1005 Union Trust Building. Mr. James Veitch, formerly of Bruce, Peebles Electric Company, Edinburgh, and recently on the staff of the Donaldson liner *Cassandra*, has joined Mr. Gray's engineering staff.

MR. RODOLFO ROTH has resigned as electrical engineer of the Buenos Aires branch of the General Electric Company, to accept the position of manager

of the machinery department of the consulting and contracting engineering firm of Buxton, Cassini and Company, at 602 Suipacha, Buenos Aires, Argentina.

MR. GEORGE W. CRAVENS, recently Western manager for the C. & C. Electric and Manufacturing Company, with headquarters at Chicago, has been appointed manager of the welding department of the same company and transferred to the home office at Garwood, N. J. Mr. Cravens is well known as a contributor to the technical press on mechanical and electrical subjects and was for many years with the General Electric Company.

MR. HENRY FLOY, consulting engineer and author of "The Valuation of Public Utility Properties," recently returned from a two months' European trip. While abroad Mr. Floy made a study of electric railway construction and operation in the cities of Italy, the underground trolley system in Vienna, the German government's single-phase railway at Bitterfeld, and European practise in high-tension lines and 60,000-volt underground cable transmission.

MR. EDGAR G. SCOTT has resigned his position as electrical engineer at Boott Mills, Lowell, Mass., to become superintendent of power and machine shops of the Ludlow Manufacturing Associates, Ludlow, Mass. Since his graduation from Worcester Polytechnic Institute in 1905 Mr. Scott has been successively connected with the Westinghouse Electric and Manufacturing Company, Boston Elevated Railway Company, and N. J. Neall, consulting electrical engineer.

Obituary

STEPHEN DUDLEY FIELD, Fel. A. I. E. E., a charter member of the Institute, died at his home in Stockbridge, Berkshire Co., Mass., on May 18, 1913. Mr. Field was born in Stockbridge on January 31, 1846, and was a son of Jonathan Edwards and Mary Ann (Stuart) Field. His father, who died in 1868, was a lawyer of high, standing in Western Massachusetts. One of his uncles, Cyrus West Field, was eminent in his day as the leader in the promotion of the then doubtful enterprise of a submarine cable across the Atlantic Ocean. The other uncles, who were men of recognized ability in public affairs, were David Dudley, Stephen J. and Henry M. Field. When the first Atlantic cable was successfully laid in 1858, a telegraph office was opened in Stockbridge in the law office of Jonathan E. Field, and Henry J. Dunham, then a law student, was the first operator. Mr. Field, then a youth of 12, immediately showed his interest in the Morse apparatus with which the office was equipped, and soon became an efficient operator. This did not materially interfere with his regular studies which he pursued at the old Williams Academy and Reid Hoffman's school in Stockbridge, and at the Dutchess County Academy in Poughkeepsie, N. Y. He went to California in 1863, entering the service of the California State Telegraph Company. The routine duties of an operator were never quite congenial to him excepting as a stepping stone to the development of his inventive talent. When the Collins Overland Telegraph organized its force at San Francisco in 1865, he became a member of the British Columbia exploring party, with which he remained until it reached Lytton, B. C. Returning to San Francisco he was appointed an inspector with the San Franciso Fire Alarm Telegraph Company, and in 1872 organized the California Electrical Works. He was then free to give wider scope to his inventive faculty which had developed with his electrical experience. He had already invented a multiple call district telegraph box, and in 1878 had built and equipped a telephone line 60 miles long with 24 stations. In 1879 he designed and subsequently perfected the utilization of the dynamo for the generation of

current for telegraph purposes, as a substitute for the galvanic battery. While this arrangement was comparatively simple in the case of a straight Morse circuit, the important problem of using it in combination with the quadruplex was ingeniously solved by Mr. Field, and it was this particular improvement which led to the introduction of the system by the Western Union Telegraph Company. The compactness of the apparatus compared with the batteries then in use, has effected a saving of hundreds of thousands of dollars in rentals in various commercial centers. Turning his attention to other uses of electricity, he took up the electric railway problem. Although handicapped by lack of capital, which was not readily available for a project generally considered visionary, he imported the Siemens machines required for the purpose, and built at Stockbridge his pioneer electric locomotive which was subsequently operated on a special track near his home, and publicly exhibited in August, 1880. Having demonstrated the practicability of his invention, a more ambitious project followed in the construction and equipment of an electric railway at the Chicago Railroad Exposition in 1883, where a regular fare was charged for passengers. This is believed to be the first commercial use of the invention, and thus the forerunner of the great development which Mr. Field fortunately lived to witness. Having, as he believed, fortified his position with patents, which included a railway conduit system, he saw an opportunity for introducing an improved stock printing telegraph in New York City. The speed of his stock printer, surpassing anything of the kind then in use, led to the organization of the Commercial Telegram Company and forced a general improvement in the quick distribution of stock quotations. During the three years devoted to this work, other inventors had been active in the promising electric railway field. There was a prospect of patent litigation which he might not be able to pursue to the end, and he deemed it wise to sell his patents to a combination of interests having ample financial resources. Mr. Field did not, however, abandon this line of work, for in 1887 he invented and constructed at the Eickemeyer works in Yonkers a direct-connected side-bar electric locomotive which was operated on the 34th Street branch of the New York elevated railroad. His later work embraced the construction and equipment of a 150-kilometer electric railway in Geneva, Switzerland, and the invention and installation of the first submarine quadruplex between Key West and Havana in 1911. Mr. Field's 109 electrical patents, entering into nearly every branch of the art, are beyond the scope of this memoir. The work of this great inventor has left its own record extending from his birthplace in the Berkshire Hills to the Pacific Coast, to Europe and to Cuba.

Remembering his splendid physique, and his mental activity, his successful career appears to have been cut short, and yet his professional experience began at so early an age that but few can hope for a more complete realization of the true mission of man on earth.

On September 30, 1871, Mr. Field married Celestine Butters at San Francisco, by whom he is survived. The other immediate members of his family now living are his son David Dudley, and daughter Virginia. Mr. Field's membership in the American Institute of Electrical Engineers dates from its foundation April 15, 1884, and he was elected a Manager on the first Board of Directors, 1884–6 He was transferred to the grade of Fellow December 13, 1912.

The funeral services were held at Saint Paul's Church, Stockbridge, May 20, 1913, the Institute being officially represented by William Maver, Ralph W. Pope and Charles A. Terry. Interment was private in the family plot at the Stockbridge Cemetery.

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LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.

*Deceased.

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Revised to June 14, 1913.

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INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915.

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Term expires July 31, 1916.
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Revised to June 14, 1913.

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ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

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ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

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Revised to June 14, 1913.

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Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
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Boston...........Feb. 13, '03	N. J. Neall	Leavitt L. Edgar, 39 Boylston St., Boston, Mass.
Chicago.................1893	Ralph H. Rice.	E. W. Allen, 1028 Monadnock Building, Chicago, Ill.
Cleveland........Sept. 27, '07	J. C. Lincoln.	R. E. Scovel, American Steel and Wire Company, Cleveland, Ohio.
Detroit Ann Arbor.Jan. 13, '11		Ray K. Holland, Cornwall Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	T. W. Behan.	P. H. Haselton, Fort Wayne Electric Works. Ft. Wayne, Ind.
Indianapolis-Lafayette.Jan. 12, '12	O. S. More.	Charles A. Tripp, 710 Majestic Building, Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles......May 19, '08	E. R. Northmore.	C. G. Pyle, 914 Hibernian Bldg., Los Angeles, Cal.
Lynn............Aug. 22, '11	W. A. Hall.	E. R. Berry, General Electric Co., Lynn, Mass.
Madison.........Jan. 8, '09	E. H. Kifer	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	H. S. Foley,	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
Milwaukee.......Feb. 11, '10	T. E. Barnum.	L. F. Reinhard, Mechanical Appliance Co., Milwaukee, Wis.
Minnesota.......Apr. 7, '02	W. T. Ryan.	Fred G. Dustin, 9 South Fifth St., Minneapolis, Minn.
Philadelphia......Feb. 18, '03	H. A. Hornor.	H. F. Sanville, 1326 Chestnut St., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	E. L. Farrar.	M. C. Turpin, Department of Publicity, W. E. and M. Company, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, 40 Bartlett Ave., Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock,	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
San Francisco.....Dec. 23, '04	H. W. Crozier.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady......Jan. 26, '03	John B. Taylor.	J. A. Dewhurst, Gen. Elec. Co., Schenectady, N. Y.
Seattle...........Jan. 19, '04	J. D. Ross.	M. T. Crawford, 608 Electric Bldg., Seattle, Wash.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
Toledo...........June 3, '07	George E. Kirk,	Max Neuber, Care of Cohen, Freidlander & Martin, Toledo, O.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
Toronto..........Sept. 30, '03	F. A. Gaby.	H. T. Case. Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	A. M. Buck.	F. G. Wilson, University of Illinois, Urbana, Ill.
Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, British Columbia Electric Railway Company, Vancouver, B. C.
Washington, D. C. Apr. 9, '03	H. C. Eddy.	C. B. Mirick, 1330 New York Avenue, N.W., Washington, D. C.

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Agricultural and Mechanical College of Texas.......Nov. 12, '09	S. E. Bowler.	E. S. Lammers, Jr. College Station, Texas.
Arkansas, Univ. of.......Mar. 25, '04	W. B. Stelzner.	G. W. Watkins, Room 25, Buchanan Hall, Fayetteville Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson.	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	E. M. Richards.	Robert L. Rooke, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost.	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	Clay M. Strait, Univ. of Cincinnati, Cincinnati, Ohio.
Clemson Agricultural College.................Nov. 8, '12	J. H. Kangeter.	H. J. Bomar, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	Robert O. Sewell.	R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, '04	L. E. Sweitzer.	Frank A. Redding, University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	J. W. Spooner.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.......Apr. 15, '03	H.C.Bartholomew	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of...........May 18, '09	L. F. Hatz.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col....Jan. 10, '08	C. A. Leech.	W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ of.........Mar. 18, '08	S. S. Schooley.	A. J. Fecht, Univ. of Kansas, Lawrence, Can.
Kentucky, State Univ. of.Oct. 14, '10	R. B. Pogue.	W. M. Lane, 216 Rose Street, Lexington, Ky.
Lafayette College........Apr. 5, '12	G. P. Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
Lehigh University.......Oct. 15, '02	W. J. Dugan.	E. F. Weaver, Lehigh University, S. Bethlehem, Pa.
Lewis Institute..........Nov. 8, '07	Ralph Kilner.	A. H. Pensholt, Lewis Institute, Chicago, Ill.
Maine, Univ of..........Dec. 26, '06	Howard O.Burgess	J. Larcom Ober, S. A. E. House, Orono, Maine.
Michigan Univ of........Mar. 25, '04	Ward F. Davidson	Edward A. Roeser, Univ. of Michigan, Ann Arbor, Mich.
Missouri, Univ of........Jan. 10, '03	H. B. Shaw.	E. W. Kellogg, 9 Engineering Building, Columbia, Mo.
Montana State Col.......May 21, '07	Lawrence Wylie.	J. A. Thaler, Montana State College, Bozeman, Mont

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Nebraska, Univ of.......Apr. 10, '08	Olin J. Ferguson.	V. L. Hollister, Station A, Lincoln, Nebraska
New Hampshire Col.....Feb. 19, '09	Robin Beach.	Clayton W. Work, New Hampshire College, Durham, N.H.
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	S. B. Sykes.	J. W. Johnson, N. C. College of A. and M. Arts, West Raleigh, N. C.
Ohio Northern Univ.....Feb. 9, '12	George E. Boesger	Harry Restofski, Ohio Northern University, Ada, Ohio.
Ohio State Univ.........Dec. 20, '02	L. R. Yeager.	John M. Strait, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Coll...........Oct. 13, '11	A. P. Little,	J. W. Harvey, 416 Hester Street, Stillwater, Okla.
Oklahoma, Univ of.......Oct. 11, '12	R. D. Evans.	L. J. Hubbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	Lance Read.	Charles E. Oakes, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	R. H. Dearborn.	C. R. Reid, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	K. P. Fuhrman.	I. S. Nippes, Pennsylvania State College, State College, Pa.
Purdue Univ............Jan. 26, '03	C. F. Harding.	A. N. Topping, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	S. Irwin Stocking.	Joseph E. O'Connell, 457 N. 8th Street, Terre Haute, Ind.
Rhode Island State Coll..Mar. 14, '13	Harry Webb.	L. A. Whittaker.
Stanford Univ...........Dec. 13, '07	G. O. Wilson.	L. M. Bussert, Stanford University, Cal.
Syracuse Univ..........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.........Feb. 14, '08	J. A. Correll.	Joseph W. Ramsey, University of Texas, Austin, Tex.
Throop College of Technology...............Oct. 14, '10	Ray Gerhart.	R. W. Parkinson, Throop Poly. Institute, Pasadena, Cal.
Univ. of Washington.....Dec. 13, '12	George Tripple.	S. R. Shave, Univ. of Washington, Seattle, Wash.
Vermont, Univ. of.......Nov. 11, '10	Walter L. Upson.	O. Krupp, 65 North Bend St., Burlington, Vt.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	Henry Woodman Clark, A. X. P. House, University, Virginia.
Wash., State Coll of......Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ........Feb. 26, '04	C. E. Wright.	A. S. Blatterman, 45 Lewis Place, St. Louis, Mo.
Worcester Poly. Inst.....Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University..........Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

Total, 47.

PROCEEDINGS
OF THE
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OF
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THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

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Vol. XXXII August, 1913 No. 8

Cooperstown Convention

The Thirtieth Annual Convention of the American Institute of Electrical Engineers, held in Cooperstown, New York, June 23rd to 27th, will go down in the annals of the Institute as one of the most successful and enjoyable ever held. In the program the technical sessions and social features were nicely balanced, so the convention proved equally desirable for those who attended either for business or for pleasure.

The technical sessions were six in number, averaging four papers to each session. The great reduction in the number of papers over that of the last two years was favorably commented upon by many of the members present as it eliminated the necessity of parallel sessions and also afforded a longer time than heretofore for the discussions, which were unusually interesting and complete.

The social and entertainment features as arranged by the Entertainment Committee, of which Mr. W. C. Smith was chairman, were especially attractive. Two motor-boats and six row-boats were provided by the committee without charge during the days of the convention and were much appreciated by many of those in attendance. The privileges of the country club adjoining the O-te-sa-ga Hotel were extended to those attending the convention, and the golf links, tennis courts, and bathing facilities were largely patronized. The Games Committee, under the chairmanship of Mr. Farley Osgood, arranged various contests with suitable prizes for the winners. The vicinity of Cooperstown with its many delightful walks and drives, and the lake with its picturesque surroundings, offered many attractions.

The O-te-sa-ga proved an excellent headquarters for the convention, the hotel being handsome and up-to-date in all its appointments, and the ballroom was utilized for the technical sessions as well as the social functions.

The total number of members and guests in attendance was 242, of which members of all grades numbered 171. Of the 71 guests in attendance, 54 were ladies. The attendance covered a wide geographical range, almost every state in the Union being represented.

Monday

The opening feature of the Convention was the reception and dance held in the ballroom of the O-te-sa-ga, Monday evening, June 23. In the receiving line were President Ralph D. Mershon, Past-President Dugald C. Jackson, President-Elect C. O. Mailloux, and Secretary F. L. Hutchinson. An orchestra was on hand and provided music during the evening. There were about 100 present on this occasion, and after the reception, dancing was continued until the small hours.

Tuesday Morning

The first technical session of the convention was held on Tuesday morning and the technical program as printed was closely adhered to throughout all the convention sessions. The discussions on most of the papers were quite lengthy and will be published in full in future issues of the Proceedings.

The opening session was called to order by President Ralph D. Mershon at 10:30 o'clock, with Vice-Presidents David B. Rushmore, Charles W. Stone, and Severn D. Sprong, Secretary F. L. Hutchinson, and Honorary Secretary Ralph W. Pope, on the platform. President Mershon took as title for his address "Some Aspects of Institute Affairs," in which he offered a number of suggestions as a result of his experience as a member and officer of the Institute. The address is printed elsewhere in this issue of the PROCEEDINGS.

President Mershon then introduced President-Elect C. O. Mailloux, who responded briefly in an appropriate address advocating the engineers taking a more active part in the civic and political questions of the day, as well as in the social and humanitarian problems. Following Mr. Mailloux's address the President announced the inability of Dr. Elihu Thomson to be present on account of illness, and on motion of Mr. C. O. Mailloux a telegram of sympathy was sent to Dr. Thomson.

The first paper on the program, "A Suggestion for the Engineering Profession", was then read by its author, William McClellan. The paper advocated the formation of a national league of engineering associations, and contained an outline for such an organization. This suggestion was received with much favorable comment and was, on motion, referred to the Board of Directors for further consideration.

The President then called upon Mr. F. F. Fowle of the Telegraphy and Telephony Committee to occupy the chair during the presentation of the next two papers, the first by Messrs. A. E. Kennelly and F. W. Lieberknecht on "Test of an Artificial Aerial Telephone Line at a Frequency of 750 Cycles per Second," and the second by Messrs. H. M. Friendly and A. E. Burns, on "Automatic Methods in Long-Distance Telephone Operation." Following the discussion of these two papers, Prof. Albert F. Ganz, chairman of the Electrochemical Committee, was called to occupy the chair and the paper on "Electrolytic Corrosion of Iron in Soils," by Burton McCollum and K. H. Logan, was presented by Mr. McCollum. Owing to the lateness of the hour the discussion on this paper was postponed until the evening session.

TUESDAY AFTERNOON

The preliminaries in the golf and tennis tournaments were held Tuesday afternoon on the grounds of the country club, and for the benefit of those who did not attend the games a concert was given by the hotel orchestra in the lobby of the hotel. A steamer excursion around Otsego Lake had been provided by the Entertainment Committee and at the close of the games practically the entire membership of the convention enjoyed the trip on the steamer "Mohican" from five to seven o'clock p.m. Music was provided by the hotel orchestra. The trip was highly enjoyed by all.

TUESDAY EVENING

The technical session for Tuesday evening was called to order by President Mershon, after which Professor Ganz took the chair during the discussion of the paper by Messrs. McCollum and Logan. A lengthy discussion on this paper followed, after which the session was turned over to the Educational Committee. In the absence of Chairman H. H. Norris, Prof. W. I. Slichter presided and presented the introduction to the report on "Industrial Education." The following papers were then presented in abstract in accordance with the program: "The National Association of Corporation Schools," by F. C. Henderschott, "Vocational Education in Philadelphia and Vicinity," by A. J. Rowland, "Vocational Training in the Far West," by Robert Sibley, and "The Pennsylvania Railroad Company Apprentice Schools," by John Price Jackson and J. W. L. Hale. The discussion of these papers extended late into the evening.

Dancing was found to be so popular

that although the ball room could not be used on account of the technical session, a room in the basement was made ready where dancing was held from 10 to 12 o'clock.

Wednesday Morning

The High-Tension Transmission Session was called to order by President Mershon at 10:30 o'clock, and Mr. Percy H. Thomas, chairman of this committee, was called upon to preside. "Suggested Specifications for Testing High-Voltage Insulators," by F. W. Peek, Jr., J. A. Sandford, Jr., and Percy H. Thomas, were presented, followed by a very full discussion, after which the papers "Constant Voltage Transmission" by H. B. Dwight, and "Theory of the Non-Elastic and Elastic Catenary as Applied to Transmission Lines," by C. A. Pierce, F. J. Adams, and G. I. Gilchrest, were presented and discussed.

While this session was in progress an automobile ride was provided for the ladies in attendance. At 10:00 a.m. about half of the ladies present started on a trip around Otsego Lake and through Richfield Springs. In providing sufficient automobiles for the trip the committee availed itself of the generosity of several of the members who volunteered the use of their cars.

Wednesday Afternoon

The Industrial Power Session was called to order Wednesday afternoon by President Mershon, and Mr. J. M. Hipple, chairman of this committee, was called on to preside. Four papers were presented in abstract and discussed, as follows: "The Behavior of Synchronous Motors during Starting," by F. D. Newbury, "Commutating Pole Saturation in Direct-Current Machines," by H. E. Stokes, "The Industrial Use of Synchronous Motors by Central Stations," by J. C. Parker, "The Electrical Requirements of Certain Machines in the Rubber Industry," by C. A. Kelsey.

During the afternoon the ladies were engaged in a shuffle-board contest on the basement floor of the hotel, and following the contest afternoon tea was served in the adjoining rooms overlooking the lake.

Wednesday Evening

At 8:30 o'clock Wednesday evening a short address illustrated with lantern slides was delivered by Mr. H. W. Crozier in the ballroom of the hotel. The subject was "The Panama-Pacific Exposition of 1915," and about 150 members and guests were present. Following this lecture the membership was invited to an electrical show which had been arranged in the basement of the hotel. This feature proved to be one of the most humorous of the convention.

Nearly all members and guests present repaired to the basement where President Mershon pushed the button and set the show in motion. The Entertainment Committee had prepared, upon the suggestion of Mr. H. A. Hornor, an exhibition of electrical apparatus and electrical terms, also advertising placards of electrical companies. There were exhibited edible "Lines of Force" which evidently could not be detected by the galvanometer; the original type of "switch;" a new type of one candle power lamp with the filament consisting of one ordinary candle; distribution of free samples of hardtack by the "Generous Electric Company." Wild spirit music purporting to emanate from a phonograph without either record or needles was wafted over the heads of assembled guests as they moved among the different exhibits. An umber of very clever skits on practically all of the electrical manufacturing companies were in evidence at this show.

A card party for the ladies was also held in the hotel parlor Wednesday evening, the tables being divided between bridge whist and hearts.

The Board of Directors held a meeting Wednesday evening, the resume of

which will be found elsewhere in this issue.

While the electrical show was in progress the ballroom was cleared and dancing was enjoyed until 1 o'clock.

Thursday Morning

President Mershon called the meeting to order promptly at 10:00 o'clock Thursday morning, the first part of the session being under the auspices of the Power Station Committee. The paper by Messrs. H. G. Stott and W. S. Gorsuch, entitled "Standardization of Method for Determining and Comparing Power Costs in Steam Plants," was presented in abstract by Mr. Stott.

Mr. Stott, the chairman of this committee, then took the chair and presided during the discussion of this paper. The remainder of the session was under the auspices of the Electric Lighting Committee, and was presided over by Mr. P. Junkersfeld of this committee. The following papers were then presented and discussed: "Automatic Substations," by H. R. Summerhayes, "Converting Substationsin Basements and Sub-Basements," by B. G. Jamieson, and "Operation of Frequency Changers," by N. E. Funk.

During the morning while the technical session was in progress a court golf tournament for the ladies was held on the hotel lawn and a large number participated.

Thursday Afternoon

A Chopin lecture recital was very kindly given by Prof. Vladimir Karapetoff Thursday afternoon in the ballroom of the hotel. A large proportion of the attendance at the convention was present at this lecture recital and all were thoroughly delighted by Prof. Karapetoff's skill as a musician.

The finals of the golf and tennis tournaments were played on Thursday afternoon, after which a baseball contest was played between the "Never-Was's" under Captain Osgood, and the "Has-Beens" under Captain Hall, who acted in place of Captain W. S. Lee, who was obliged to leave before the game took place.

Thursday Evening

The ceremony of the presentation of the Edison Medal to Mr. William Stanley took place at 9:00 Thursday evening, the session being called to order by President Mershon. In the absence of Dr. Elihu Thomson, chairman of the Committee on Award, President Mershon called on Mr. C. O. Mailloux, who made the presentation address. Mr. Mailloux referred to his personal acquaintance with the recipient extending over 30 years and briefly recounted Mr. Stanley's career in the electrical field and pointed out many of his notable inventions.

President Mershon then presented the Medal to Mr. Stanley, stating that he well remembered, when he first started in engineering work many years ago, in the company with which Mr. Stanley had recently been connected, the admiration which he felt for the many evidences of Mr. Stanley's creative work which he saw at that time. That admiration had continued until the present day, and he therefore felt the more pleasure because of that admiration in presenting Mr. Stanley with the Medal, which had been awarded to him by the Edison Medal Committee.

Mr. Stanley responded briefly and spoke of the debt which the present generation owes to the early scientists and inventors in the electrical field. He also referred to the many epoch-making discoveries of the last ten years, and closed by stating that it is the privilege as well as the joy of the engineer and inventor to translate the great discoveries of science into material form, to apply the laws of nature, as they are gradually discovered, to new uses for the benefit of man. Each application of these principles eases the burden of man, removes the fears of ignorance, and marks the advance toward a better, happier and richer life.

Following the presentation of the Edison Medal there was held the scheduled conference of Section Delegates, which is reported more in detail on the following page.

During the evening a concert was also given in the lobby by the hotel orchestra, and following the concert the last dance of the convention was enjoyed until the early hours.

Friday Morning

The final session of the convention was held Friday morning and was called to order by President Mershon, who turned the meeting over to Professor John B. Whitehead, chairman of the Electrophysics Committee. The following papers were then presented in abstract and discussed: "The Electric Strength of Air—IV," by J. B. Whitehead and T. T. Fitch, "The Positive and the Negative Corona and Electrical Precipitation," by W. W. Strong, "Law of Corona and Dielectric Strength of Air—III," by F. W. Peek, Jr., "An Oscillograph Study of Corona," by Edward Bennett. The close of the discussion on these papers marked the end of the convention, which proved both pleasant and profitable to everyone who attended.

Winners of Contests at the Convention

Golf. Mr. A. M. Schoen, of Atlanta, won the first prize in the golf tournament, which entitles him to have his name inscribed upon the Mershon Golf Trophy contributed by the President. This cup is to be finally awarded to the man winning the golf championship in two different years at the annual convention. Prof. C. A. Adams won the second prize in golf.

Tennis. The tennis tournament was won by Mr. G. A. Sawin; second prize going to Mr. C. T. Mosman.

Ladies' Court Golf. The first prize was awarded to Mrs. N. M. Garland, and the second prize to Mrs. E. B. Craft.

Shuffleboard. The prize was awarded to Miss E. E. Maver.

Card Party. The first and second prizes at bridge whist were won by Mrs. E. J. Cheney and Mrs. G. A. Sawin, respectively. The first prize at hearts was won by Mrs. W. J. Foster and the second prize by Mrs. D. J. Coughlin.

Baseball. The Has-Beens, Captain Hall, won this game, the score being 13 to 8. The prize for longest hit was awarded to Mr. Charles T. Mosman. The prize for most strike-outs was won by Mr. G. A. Sawin. Mr. F. D. Newbury, Mr. M. G. Lloyd and Mr. W. L. Upson were tied for the greatest number of runs scored.

Fishing. The prize for the greatest number of fish caught was awarded to Mr. E. B. Merriam, and that for the largest fish caught was awarded to Mr. E. B. Craft.

Automobile Trip to Convention. The prize for the longest automobile trip to the convention was awarded to Mr. Paul M. Lincoln of Pittsburgh.

Conferences of Section Delegates

In order to provide ample time for the Section Delegates to exchange experiences in regard to the administration of Section affairs, as well as to discuss the relations of the Sections to the Institute, Chairman P. M. Lincoln arranged to have the delegates lunch together on June 24th, 25th, and 26th. These luncheons were attended by all the Section Delegates as well as a number of officers of the Institute, and the discussions which took place on these occasions proved of so much interest that the meetings continued in session until 4 or 5 o'clock each afternoon. The following Section Delegates were in attendance at the Convention:

A. M. Schoen,	Atlanta.
J. B. Whitehead,	Baltimore.
N. J. Neall,	Boston.
Ralph H. Rice,	Chicago.
J. C. Lincoln,	Cleveland.
A. R. Sawyer,	Detroit–Ann Arbor.
P. H. Haselton,	Fort Wayne.
J. Lloyd Wayne,	Indianapolis-Lafayette

F. Bedell,	Ithaca.
W. A. Hall,	Lynn.
E. Bennett,	Madison.
A. L. Abbott,	Minnesota.
H. A. Hornor,	Philadelphia.
E. L. Farrar,	Pittsburgh.
W. C. Smith,	Pittsfield.
H. M. Friendly,	Portland.
H. W. Crozier,	San Francisco.
J. B. Taylor,	Schenectady.
M. T. Crawford,	Seattle.
F. J. Bullivant,	St. Louis.
Max Neuber,	Toledo.
J. B. Fisken,	Spokane.
A. M. Buck,	Urbana.
F. D. Nims,	Vancouver.

A great many questions in regard to the conduct of Section affairs were propounded and discussed. There was a general sentiment among the delegates, that the interests of the Institute as well as the Sections would be advanced by a more intimate relation between the Sections and the governing body of the Institute, and various methods of augmenting the activities of the Sections and furthering their influence in shaping the policies of the Institute were proposed and discussed.

These informal meetings of the Section Delegates, besides bringing out many suggestions, were also of great advantage in permitting exchange of experiences between the various delegates in regard to problems which arise in the conduct of Sections meetings, and a number of resolutions for furthering the interests of the Sections were adopted and referred to the Board of Directors.

The scheduled conference of Section Delegates was held on the evening of June 26th. President Mershon called the meeting to order and turned it over to Chairman Lincoln, who presided during the evening. The chairman called upon each delegate to describe briefly the conditions of the Section which he represented, the various problems which had occurred in the administration of the Section, and the remedies which had been applied to various difficulties. The conference was in fact an experience meeting in which the delegates gathered from each other such ideas in regard to the operation of the other Sections as would assist them in the operation of their own sections during the coming year. With very few exceptions the problems of most of the Sections were of the same general character, namely, securing adequate attendance at the meetings, procuring papers of a character which would insure wide attention, providing entertainment features, and other means of insuring the general interest of the membership.

The keynote of the situation was probably struck by one of the delegates who reported great increase of interest and activity in his Section following a policy of giving everybody something to do. Work always creates interest, therefore let every member get to work for his Section.

For the benefit of Section representatives, advance sheets of the full minutes of these conferences have been forwarded to them, and later a complete report will be published in pamphlet form, and will be available to any member, on request to the Secretary.

Pacific Coast Convention, Vancouver, B. C., September 9-11, 1913

The tentative program of the Pacific Coast Meeting of the Institute to be held in Vancouver, B.C., September 9–11, 1913, was printed in the July PROCEEDINGS. The definitive program, as arranged by the local committee will be mailed to all Pacific Coast members of the Institute in advance of the meeting. The papers for this meeting were not received in time to be included in this issue of the PROCEEDINGS, and it has therefore been arranged to distribute advance copies, as soon as they are available, from the office of the secretary of the Convention Committee, Mr. E. M. Breed, 814 Dominion Trust Bldg., Vancouver, B. C., to whom application should be made for copies of these papers.

Directors' Meeting, June 25, 1913

The Board of Directors of the Institute held a meeting during the Annual Convention, at Cooperstown, N. Y., on June 25, 1913.

The Directors present were: Messrs. Ralph D. Mershon, President, New York; Dugald C. Jackson, Boston, Mass., and Gano Dunn, New York, Past-Presidents; David B. Rushmore and Charles W. Stone, Schenectady, N. Y., A. W. Berresford, Milwaukee, Wis., S. D. Sprong, New York, Vice-Presidents; W. S. Rugg, C. E. Scribner and William McClellan, New York, W. S. Lee, Charlotte, N. C., Farley Osgood, Newark, N. J., Comfort A. Adams, Cambridge Mass., J. Franklin Stevens, Philadelphia, Pa., Managers; and F. L. Hutchinson, New York, Secretary.

The action of the Finance Committee in approving monthly bills amounting to $10,188.51 was ratified.

The report of the Board of Examiners of its meeting on June 17 was approved.

Upon the recommendation of the Board of Examiners, 64 applicants were elected to the grade of Associate, and 71 applicants were enrolled as students. The names of these Associates and students are printed elsewhere in this issue.

William Valentine Hunt, British Columbia Electric Railway Company, Ltd., Vancouver, B. C., was elected to the grade of Member.

Ezechiel Weintraub, General Electric Company, Lynn, Mass., was elected to the grade of Fellow.

Henry Graftio, Ministry of Ways of Communication, St. Petersburg, Russia, was transferred from the grade of Member to the grade of Fellow.

The special committee appointed to examine applications for transfer to the grades of Member and Fellow, filed under the special section of the Constitution prior to May 1, 1913, reported a list of 22 applicants for transfer to the grade of Fellow, and 63 applicants for transfer to the grade of Member, whose applications the committee had examined and found to comply with the requirements of the special section. These 85 applicants were thereupon transferred to the grades indicated.

All the Institute committees whose terms of office, under the Constitution, expired at this Directors' meeting, were reappointed by President Mershon to serve until the expiration of the current administrative year, July 31, 1913.

Convention of Illuminating Engineering Society in Pittsburgh

On September 22–26 the convention of the Illuminating Engineering Society will be held in Pittsburgh, with headquarters at the Hotel Schenley.

The program includes an interesting set of papers on various subjects pertaining to illumination, among them being papers on the quartz light, Fontune and neon tube; flame carbon arc lamp; church, factory, store, hospital and street car lighting; the present commercial development in several forms of lighting; errors in photometric measurement; and the history of artificial lighting.

Inspection trips will be arranged to several industrial plants in the vicinity, and the local committee has planned a series of entertainment features, in which the ladies are included.

United States Civil Service Examination for Radio Sub-Inspector

The United States Civil Service Commission announces an open competitive examination for radio subinspector, for men only, on August 20, 1913. From the register of eligibles resulting from this examination certification will be made to fill a vacancy in this position at $6 per diem and a vacancy in the position of assistant radio subinspector at $4 per diem, in the Navy Yard, New York, N. Y., and vacancies as they may occur in positions throughout the United States requiring similar qualifications, at entrance salaries ranging from $4 to $6 per diem.

Applicants for this position should

preferably be graduates of high-class technical schools and have taken a course in electrical engineering or a special course in wireless telegraphy; also should have had several years' experience in the manufacture, installation, and adjustment of wireless apparatus. They should be expert operators and be able to prepare useful reports of inspections and tests.

Citizens of the United States who meet the requirements and desire this examination should at once apply to the United States Civil Service Commission, Washington, D. C., for application Form 1312.

Addresses Wanted

Name	Former address
Adolph L. Fisher,	104 Peabody St., Gardner, Mass.
Donald S. Hayes,	Portland, Ore.
Milo T. Keister,	1570 Lincoln St., Denver, Colo.
Miles H. Roffey,	2242B 8th Ave., West, Vancouver, B. C.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

Recommended for Transfer to the Grade of Fellow, June 17, 1913

The Board of Examiners, at its regular monthly meeting on June 17, 1913, recommended the following members of the Institute for transfer to the grade of Fellow. Any objection to these transfers should be filed at once with the Secretary.

CLARK, FARLEY G., Chief Engineer, Toronto Power Co., Ltd., Toronto, Ont.

DOHERTY, HENRY L., President, Cities Service Co., New York, N. Y.

FARMER, F. M., Chief Engineer, Electrical Testing Laboratories, New York, N. Y.

FISKEN, JOHN B., Superintendent of Light and Power, Washington Water Power Co., Spokane, Wash.

SCHICK, D. FREDERICK, Superintendent of Distribution, Philadelphia Electric Co., Philadelphia, Pa.

WALLS, JOHN A., Chief Engineer, Pennsylvania Water & Power Co., Baltimore, Md.

WILSON, ROBERT M., General Superintendent and Chief Engineer, Montreal Light, Heat & Power Co., Montreal, Canada.

Transferred to the Grade of Fellow, June 25, 1913

The following were transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on June 25, 1913.

RECOMMENDED FOR TRANSFER BY THE BOARD OF EXAMINERS

GRAFTIO, HENRY, Ministry of Ways of Communication, St. Petersburg, Russia.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

BENECKE, A. O., Consulting Electrical Engineer, Boston, Mass.

CHENEY, H. W., Engineer, Electrical Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

CLEMENT, EDWARD E., Patent Attorney and Electrical Expert, Washington, D. C.

DOOLITTLE, CLARENCE E., Consulting Engineer, Vice-President and General Manager, Roaring Fork Elec. Lt. & Pr. Co., Aspen, Colo.

ESTY, WILLIAM, Professor of Electrical Engineering, Lehigh University, South Bethlehem, Pa.

FERGUSON, O. J., Head Professor of Electrical Engineering, University of Nebraska, Lincoln, Nebr.

FISH, WALTER C., Manager, Lynn Works, General Electric Co., West Lynn, Mass.

GHERKY, WILLIAM D., Engineer and Contractor, Philadelphia, Pa.

HEATHER, H. J. S., London, England.

HENDERSON, R. H., Manager of Works, Westinghouse Lamp Co., Bloomfield, N. J.

KNIGHT, CHARLES D., Engineer, Industrial Control Dept., General Electric Co., Schenectady, N. Y.

LEONARZ, E., Manager, Monterey Railway, Light & Power Co., Monterey, N. L., Mex.

MERZ, CHARLES H., Consulting Engineer, London, S. W., England.

NICHOLS, LOUIS C., Engineer in charge Bullock Works, Allis-Chalmers Co., Norwood, Ohio.

NORTHRUP, EDWIN F., Research Work in Electrical Science, Palmer Physical Laboratory, Princeton, N. J.

PESTELL, WILLIAM, Superintendent of Power and Lines, The Rhode Island Co., Providence, R. I.

POOLE, C. O., Chief Engineer, Nevada-California Power Co., LosAngeles,Cal.

PRATT, WILLIAM H., Electrical Engineer, General Electric Co., West Lynn, Mass.

REBER, HENRY LINTON, Vice-President and General Manager, Kinloch Telephone System, St. Louis, Mo.

REIST, HENRY G., Designing Engineer, General Electric Co., Schenectady, N. Y.

WILSON, ROBERT L., Superintendent Railway Dept., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

WRAY, J. G., Chief Engineer, Central Group of Bell Telephone Companies, Chicago, Ill.

Total, 23.

Fellow Elected June 25, 1913

WEINTRAUB, EZECHIEL, Director Research Laboratory, General Electric Co., West Lynn, Mass.

Transferred to Grade of Member, June 25, 1913

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on June 25, 1913.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

ALEXANDERSON, E. F. W., Consulting Engineer, General Electric Co., Schenectady, N. Y.

ARMSTRONG, R. W., Electrical Engineer, Safety Car Heating and Lighting Co., Jersey City, N. J.

ASHLEY, EDWARD E., Jr., Consulting Engineer, New York, N. Y.

BAILEY, BENJAMIN F., Professor of Electrical Engineering, University of Michigan, Ann Arbor, Mich.

BARKER, HARRY, Associate Editor, *Engineering News*, New York, N. Y.

BEAM, VICTOR S., Consulting Electrical and Mechanical Engineering, New York, N. Y.

BEEBE, C. N., Engineer and Salesman, Canadian Westinghouse Co., Vancouver, B. C.

BLAKE, HENRY W., Editor, *Electric Railway Journal*, New York, N. Y.

BOESCH, J. E., Distributing Engineer, British Columbia Electric Railway, Vancouver, B. C.

BOZELL, HAROLD V., Director, School of Engineering, University of Oklahoma, Norman, Okla.

BRINKERHOFF, A. D., Secretary-Treasurer, National Light & Power Co., St. Louis, Mo.

BURKE, JOSEPH HENRY, Chief Inspector Department of Water Supply, Gas and Electricity, Long Island City, N. Y.

BUSSEY, H. E., District Engineer, General Electric Co., Atlanta, Ga.

CALDWELL, EDWARD, Treasurer, McGraw-Hill Book Co., New York, N.Y.

CAMPBELL, GEORGE A., Research Engineer, American Tel. & Tel. Co., New York, N. Y.

CHATTO, BYRON H., Designing Engineer, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

CORNICK, TULLY R., Contracting Engineer, Vancouver, B. C.

CROUSE, DAVID E., Electrical Engineer, Maryland Electric Railways Co., Annapolis, Md.

DEGEN, LOUIS, Construction Engineer, with Chas. G. Armstrong, New York, N. Y.

DOOLEY, C. R., In charge Educational Work, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

DUNBAR, GLENDOWER, Chief Electrical Engineer and Assistant Superintendent, City Lighting Department, Seattle, Wash.

EDDY, H. C., Engineer, Public Utilities Commission, Washington, D. C.

FISK, I. W., Instructor in Electrical Engineering, University of Illinois, Urbana, Ill.

FRANKENFIELD, BUDD, Los Angeles, Cal.

GARCELON, G. H., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GILBERT, CHARLES H., Supervisor of Traffic, American Tel. & Tel. Co., New York, N. Y.

HARTMAN, F. S., District Manager, Power & Mining Dept., General Electric Co., New York, N. Y.

HEINZE, CARL A., Assistant Electrical Engineer, Bureau of Los Angeles Aqueduct, Los Angeles, Cal.

HOUGH, HARRY W., Assistant Electrical Engineer, Cleveland Electric Illuminating Co., Cleveland, O.

HUTTON, S. E., Consulting Electrical and Mechanical Engineer, Moscow, Idaho.

JAMES, LEONARD V., Instructor in Electrical Engineering, University of Illinois, Urbana, Ill.

JENKS, LESLIE H., General Superintendent, Northwestern Tel. & Tel. Co., Carthage, N. Y.

JONES, FRANK P., JR., Commercial Engineer, Power & Mining Dept. General Electric Co., Philadelphia, Pa.

KERR, WILLIAM A., Resident Superintendent, Shawinigan Water & Power Co., Shawinigan Falls, P. Q.

KILBURN, ERNEST E., Electrical Engineer, Shore Line Electric Railway Co., Madison, Conn.

LIPPELT, HANS B., Engineering Dept., New York Edison Co., New York, N. Y.

LYNCH, H. B., Manager, Electric Light Plant, Glendale, Cal.

MALLET, JOHN P., Electrical Engineer, Diehl Manufacturing Co., Elizabeth, N. J.

MANAHAN, R. H., City Electrician, Los Angeles, Cal.

MERRILL, MELDEN H., Vice-President, Concord, Maynard & Hudson Street Railway Co., Boston, Mass.

MILLAR, T. R., Electrical Engineer, Smith, Kerry & Chace, Toronto, Ont.

MOTTINGER, BYRON T., Consulting Engineer, Youngstown, Ohio.

MURMANN, F. J., Superintendent of Substations and Meter Dept., Westchester LightingCo., Mt. Vernon, N.Y.

NEWBURY, F. D., Designing Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

NEWMAN, LOUIS J., Electrical Engineer, New York, N. Y.

ORTH, C. L., Representative, Allis-Chalmers Co., St. Louis, Mo.

PARSONS, WILL H., General Manager, Shearer Electrical Construction Co., Mexico City, D. F.

PEEK, FRANK W., JR., Consulting Engineer, General Electric Co., Schenectady, N. Y.

RITTER, HANS K., Electrical and Illuminating Engineer, Niagara Falls, N. Y.

ROSE, GEORGE S., Sales Dept., General Electric Co., New York, N. Y.

SCHREIBER, HERMANN V., Managing Engineer, Sellers & Rippey, Philadelphia, Pa.

SEYFERT, STANLEY S., Assistant Professor of Electrical Engineering, Lehigh University, South Bethlehem, Pa.

SHUFF, FRANK K., Superintendent, Ft. Dodge, Des Moines & Southern Railway, Boone, Iowa.

SMITH, ARTHUR BESSEY, Consulting Electrical Engineer, Automatic Electric Co., Chicago, Ill.

TOBEY, H. W., Engineer in Transformer Dept., General Electric Co., Pittsfield, Mass.

VINSON, S. GLEN, Secretary and General Manager, Ideal Electric & Mfg. Co., Mansfield, Ohio.

VROOMAN, H. H., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

WIARD, JOHN B., General Electric Co., West Lynn, Mass.

WILLIAMS, WYNANT J., Assistant Professor of Physics, Rensselaer Polytechnic Institute, Troy, N. Y.

WINTNER, LOUIS J., Sales Engineer, General Electric Co., New York, N. Y.

WOOD, C. P., Engineer and Salesman, Standard Gas Power Co., Atlanta, Ga.

WRIGHT, C. H., District Manager and Electrical Engineer, Canadian General Electric Co., Halifax, N. S.

YUNDT, GEORGE J., Chief Engineer, Southern Bell Tel. & Tel. Co., Atlanta, Ga.

Total, 63.

Member Elected June 25, 1913

HUNT, WILLIAM VALENTINE, Electrical Engineer, British Columbia Electric Railway Co., Ltd., Vancouver, B. C.

Associates Elected June 25, 1913

BARRON, GEORGE F., Apprentice Engineer, Allis-Chalmers Co.; res., 4815 Linden Ave., Norwood, Ohio.

BEGG, REGINALD H., Electrical Engineer, Municipal Tramways Trust, Adelaide; res., The Semaphore, South Australia.

BEHNKE, RICHARD E., Engineer Draftsman, with C. O. Lenz, 71 Broadway, New York; res., 37 Sterling Pl., Brooklyn, N. Y.

BLAIR, SHIRAS A., Student, University of Alabama, Tuscaloosa, Ala.

BRANT, CLIFFORD A., Secretary and General Manager, Toms River & Island Heights Electric Light & Power Co., Toms River, N. J.

BROWN, HARRY M., Chief Clerk, Philadelphia Electric Co., 28th & Christian Sts., Philadelphia, Pa.

BUBKE, HENRY PETER, Sub-station Operator, Spokane & Inland Empire Railroad, Spokane, Wash.

BUCHER, PAUL, Engineer, Pacific Gas & Electric Co., 7th & Market Sts.; res., 1217 Jones St., San Francisco, Cal.

CANNIFF, STANLEY W., Assistant Supply Dept. Engineer, Canadian General Electric Co., King & Simcoe Sts., Toronto, Ont.

CARLSON, FRED W., Inside Installation Work, Helena Electric Co., Helena, Mont.

CHRISTIANS, GEORGE W., Testing Dept. New York Edison Co., 92 Vandam Street, New York, N. Y.

CHRYSSIDY, STEPHEN S., Electrical Engineer, M. Buarque & Company, 126 Rua Sao Pedro, Rio de Janeiro, Brazil.

COLE, ALBERT E., Electrician, E. & M. Electrical Co., 35 Hartford St., Boston; res., 65 Clifford St., Roxbury Mass.

COMBS, ROBERT H., General Traffic Manager, The Prest-O-Lite Co., 2238 College Ave., Indianapolis, Ind.

CSANYI, HENRY, Electrical Engineer, Maxivolt Primary Battery Co., 449 West 28th St.; res., 435 East 138th St., New York, N. Y.

DE SOUZA, EDGARD E., Professor of Electrical Engineering, Escola Polytechnica de Sao Paulo, Sao Paulo, Brazil.

DOZIER, JOSEPH GORDON, Electrical Engineer, with H. E. Allard, 514 Atlantic Ave., Boston; res., 48 Walnut St., Palmer, Mass.

EAGER, WILLIAM G., General Manager, Valdosta Lighting Co.; res., 205 W. Gordon St., Valdosta, Ga.

ELLIS, PHILIP W., Chairman, Toronto Electric Commissioners, 31 Wellington St., East, Toronto, Ont.

ELMORE, FRANK H., Jr., Student, Bliss Electrical School, Washington, D. C.

ELWELL, DAVID, Electrical Engineer, Lockwood, Greene & Co., 60 Federal Street, Boston, Mass.

GODFREY, HARVEY, Instructor of Applied Electricity, New York Electrical School, 39 West 17th St., New York, N. Y.

GRAY, ROBERT L., Assistant Electrical Engineer, Electrical Branch, Public Works Dept., Christchurch, N. Z.

GUISE, HIRAM B., Chief Engineer, Rubber Regenerating Co.; res., 201 South Church St., Mishawaka, Ind.

HAMLIN, ERNEST JOHN, Lecturer in Electrical Engineering, South African College, Cape Town, S. A.

HARFORD, ALBERT K., Manager, Municipal Light & Power Co., 705 Market Street, San Francisco, Cal.

HAYNES, HAROLD A., Instructor in Engineering Dept., Howard University, Washington, D. C.

HEISSLER, LOUIS J., Construction Foreman, Isthmian Canal Commission, Pedro Miguel, C. Z.

HENDRY, LAURENCE G., Manager, Hendry-Crossman Electric Co., Ltd., 1260 Hamilton St., Vancouver, B. C.

HENRY, WILLOUGHBY JOHN, Engineer, 522 Metropolitan Building, Hastings St., Vancouver, B. C.

HOLDER, EDWARD, District Representative, Sales Dept., British Columbia Electric Ry. Co., Ltd., Vancouver, B. C.

HOLLYDAY, J. E., Electrician, Electric Tachometer Co., Broad & Spring Garden Sts., Philadelphia, Pa.

HUGHES, ADRIAN, JR., Assistant, Electrical Dept., Carnegie Steel Co., Braddock, Pa.

IRWIN, ALVIN EARL, Kansas City Electric Light Co., 1500 Grand Ave.; res., 2515 Troost Ave., Kansas City, Mo.

JENSON, JEAN S., Designing Engineer, Pierce, Richardson & Neiler, Room 1409 ,431 S. Dearborn St., Chicago, Ill.

KEMPTON, GEORGE R., Electrical Engineer, 54 West Balcom Street, Buffalo, N. Y.

KRAMER, FRANK E., Chief Electrician, Aultman & Taylor Co.; res., 240 West 4th Street, Mansfield, Ohio.

LATIMER, JAMES STANLEY, Superintendent of Station Repairs, Hydro Electric Power Commission, Dundas, Ont.

LONG, HUBERT D., Utah Power & Light Co., Salt Lake City, Utah.

MACKE, C. J., Electrical Engineer, McCleary, Wash.

MACKENZIE, KENNETH G., Consulting Chemist, The Texas Co.; res., 233 Avenue A., Bayonne, N. J.

MASAKI, RYOICHI, Electrical Engineer, Inawashiro Hydro-Electric Power Co., Tokyo, Japan.

MASUDA, MOTOSUKE, Electrical Engineer, Electrical Bureau of the Tokio Municipality, Tokio, Japan.

METZ, GEORGE F., Electrical Dept., Lehigh Valley Coal Co., Market Bank Bldg., Hazleton, Pa.

MILLER, FERDINAND C., Jr., Superintendent of Electricity, Powell River Co., Ltd., Powell River, B. C.

MITCHELL, CHARLES W., Electrical Inspector, Fire Department, 157 E. 67th Street, New York, N. Y.

MORELAND, CLAUDE M., Construction Foreman, General Electric Co., Schenectady, N. Y.

NEHER, ANTHONY, Commercial Engineer, Sprague Electric Co., 516 Fisher Bldg., Chicago, Ill.

PEARCE, W. R., Plant Superintendent, Alberta Government Telephones, Edmonton, Alberta, Can.

PLOWMAN, REGINALD C., Electrical Engineer, A. E. G. Cia. Mexicana de Electricidad, S. A., Mexico, D. F., Mex.

POSPISIL, L. J., Engineer in charge of designs, Washington Water Power Co.; res., 103 W. 17th Ave., Spokane, Wash.

PURTON, THOMAS ANTHONY, Draughtsman, Electrical Engineering Dept., Oregon Short Line Railroad, Salt Lake City, Utah.

ROHRBACH, FRANKLIN L., Engineer in charge of underground system, Washington Water Power Co., Spokane, Wash.

SCOULER, GAVIN T., Asst. Inspector of Gas & Electricity, Dominion Government, 712 Pender St., W., Vancouver, B. C.

SELDOMRIDGE, CARROLL H., Test Dept., Southern California Edison Co.; res., 1276 West 25th Street, Los Angeles, Cal.

STARK, LEOPOLD, Manager of Municipal Electric Supply Works; res., II Nyulutca 5, Budapest, Hungary.

STEVENS, JOHN F., Teacher in Electrical Engineering, University of North Dakota, University, N. D.

TAGHOLM, GROVER, Construction Foreman, Western Electric Co.; res., 3405 26th St., Chicago, Ill.

TEMPLIN, ARTHUR G. W., Engineer, Edison Illuminating Co., 18 Washington Blvd.; res., 86 Linwood Ave., Detroit, Mich.

TUCKER, JOHN, JR., Student, Stevens Institute of Technology, Hoboken, N. J.

VAN NORMAN, MYRON A., Chief Electrician, Hudson Motor Car Co.; res., 238 Montclair Ave., Detroit, Mich.

WATERHOUSE, JAMES K., Treasurer and General Manager, Portland Power & Railway Co., Damariscotta, Me.

WINTER, TORSTEN G., Engineer, Western Canada Power Co.; res., 1788 Haro St., Vancouver, B. C.

WRIGHT, ROBERT V., Electrical Engineer, J. B. Ferguson & Co., Hagerstown, Md.

Total, 64.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1913.

Abrahams, S. L., Lynn, Mass.
Ackerman, P., Toronto, Ont.
Adler, E., London, W., Eng.
Alden, F. A. (Member), Cambridge, Mass.
Allen, J. D., Kansas City, Mo.
Bates, F. J., Surrey, Cal.
Bearce, W. D., Scotia, N. Y.
Bennett, C. S., San Francisco, Cal.
Berry, F. E., Middlesex, Eng.
Bockoven, L. M., Los Angeles, Cal.
Bonfield, H. T., Seattle, Wash.
Brown, M. G., So. Fort George, B. C.
Cardew, J. H., Moghalpura, India.
Connery, F. C., Toronto, Ont.
Darnbrough, S., Kamloops, B. C.
Dogherty, A. C., Montreal, Que.
Fitzpatrick, W. J., Watervliet, N. Y.
Fleming, E., Invercargill, N. Z.
Gaillard, D. S., Culebra, C. Z.
Glaser, L. T., Wenatchee, Wash.
Gowda, C. R. B., Sivasamudram, India.
Hall, R. D., Brooklyn, N. Y.
Hay, A., Bangalore, S. India.
Hord, T. A., Jr., Dallas, Texas.
Johansson, H. J., Stockholm, Sweden.
King, L. V., Montreal, Que.
Kluge, H. M., Bloomfield, N. J.
Kobayakawa, T., Tokyo, Japan.
Langan, T. R., Baltimore, Md.
Lynn, Scott, Rochester, N. Y.
Mommo, E. J., Holtwood, Pa.
Mooney, H. V., San Francisco, Cal.
Neild, J. F., Toronto, Ont.
Orpin, Cyril, Kearsney, Eng.
Palmer, P. E., Indianapolis, Ind.
Pannell, E. V., Toronto, Ont.
Perkins, H. F., Schenectady, N. Y.
Pohe, S. C., Bloomsburg, Pa.
Porter, W. T., St. Catherines, Ont.
Setti, S. V., Bangalore, India.
Shand, Robert (Member), West Lynn, Mass.
Smith, A. L., Jr., West Medway, Mass.
Sproule, T. (Member), Philadelphia, Pa.
Summers, H. B., Davenport, Iowa.
Thomas, H. P., Nelson, B. C.
Uhlendorf, E. D., Portland, Ore.
Veerhusen, H. H., New York, N. Y.
Wathen, T. N., Gatun, C. Z.
Whitehead, R. H. (Member), Pedro Miguel, Panama.
Woestmann, F. O., Brooklyn, N. Y.
Total, 50.

Students Enrolled June 25, 1913

5897 Beaudette, J., Worcester Poly Inst.
5898 Davis, S. H., Mass. Inst. Tech.
5899 Gere, W. N., Mass. Inst. Tech.
5900 Gilson, W. J., Worcester Poly Inst.
5901 Whately, H. E., Univ. of Toronto.
5902 Mayes, G. W., Univ. of Illinois.
5903 Hoyt, H. V., Purdue University.
5904 Bryan, H. T., Ohio State Univ.
5905 Merion, N., Ohio State Univ.
5906 McCartney, J.V., Ohio State Univ.
5907 Babbitt, E. C., Ohio State Univ.
5908 Le Boutillier, A., Yale University.

5909 Laine, G. W., Jr., Ga. School Tech.
5910 Baugher, E. J., West Va. Univ.
5911 Burgi, H., Jr., Columbia Univ.
5912 Hamilton, B. P., Columbia Univ.
5913 Swan, P. K., Univ. of Wisconsin.
5914 Smeltzer, L. P., Yale University
5915 Vance, W. S., Lewis Institute.
5916 Merriell, E. W., Univ. of Minn.
5917 Caldwell, T. S., Univ. of Syracuse.
5918 Howse, C. L., Univ. of Syracuse.
5919 Seeger, E. W., Ohio State Univ.
5920 Klag, F. W., Ohio State Univ.
5921 Wolff, D. R., Ohio State Univ.
5922 McAdams, L. L., Ohio State Univ.
5923 Kuechle, T. F., Ohio State Univ.
5924 Burt, P. V., Mass. Inst. Tech.
5925 Ostrander, R. M., Rose Poly. Inst.
5926 Olson, A. E., Lehigh University.
5927 Gooderham, J. W., Univ. of Wash.
5928 Coote, J. A., McGill University.
5929 Tilley, G. G., University of Maine.
5930 Murray, W. A., Univ. of Idaho.
5931 Wright, K. W., Univ. of Kansas.
5932 Ready, W. A., Mass. Inst. Tech.
5933 Leonard, R. E., Mass. Inst. Tech.
5934 Butler, M. B., Jr., Carnegie Inst. Tech.
5935 Littell, A. S., Worcester Poly Inst.
5936 Goldenberg, C. C., Pa. State Coll.
5937 Thayer, G. R., Mass Inst. Tech.
5938 Katzenberger, W. D., Mass. Inst. Tech.
5939 Segel, H., Ga. School of Tech.
5940 Essig, T. D., Iowa State College.
5941 Hodges, R. C., Univ. of Maine.
5942 Markle, E. W., Penna State Coll.
5943 Stuckeman, W. F., Carnegie Inst. Tech.
5944 Weaver, E. F., Lehigh University.
5945 Lovell, J. W., Mass. Inst. Tech.
5946 McRobbie, H. W., Univ. of Wash.
5947 Kirsch, K., Wash. State College.
5948 Appert, H. J., Jr., Stevens Inst.
5949 Thompson, G. H., McGill Univ.
5950 Lindsay, H., Worcester Poly Inst.
5951 Blanchard, R. C., Univ. of Maine.
5952 Flansburg, P. LeR., Mass. Inst. Tech.
5953 Overpeck, G. G., Rose Poly. Inst.
5954 Peterson, A. J. A., Carnegie Inst. Tech.
5955 Lovejoy, S. H., Wentworth Inst.
5956 Johnston, H. H., Carnegie Inst. Tech.
5957 Little, G. T., Wentworth Inst.
5958 Hack, D. G., Michigan Agri. Coll
5959 Katzenstein, V. G., Mass. Inst. Tech.
5960 Coy, R., Univ. of Washington.
5961 Horrell, C. R., Univ. of Illinois.
5962 Bunn, G. F., Georgia School Tech.
5963 Pierce, G. K., State Univ. of Iowa.
5964 Lord, L., State Univ. of Iowa.
5965 Munson, S. L., Univ. of Syracuse.
5966 Burleigh, A. C., Wor. Poly. Inst.
5967 Jones, M.L., Univ. of Washington.

Total, 71.

Past Section Meetings

Baltimore

The May meeting of the Baltimore Section was held in the physical laboratory of the Johns Hopkins University on May 30. Mr. J. B. Scott presented a paper on "The High-Pressure Fire System of Baltimore," which was discussed by many of the members present.

The annual election of officers was held, with the following result: chairman, Dr. J. B. Whitehead; secretary, Mr. L. M. Potts; executive committee, J. B. Whitehead, L. M. Potts, A. S. Loizeaux, A. T. Clark, W. H. Swift, R. C. Faught, F. T. Iddings, F. A. Allner, C. G. Edwards.

Chicago

A meeting of the Electrical Section, Western Society of Engineers, was held jointly with the Chicago Section A. I. E. E. on Monday evening, April 28, with about 85 members present. The meeting was called to order by Chairman R. H. Rice, who announced that the election of members of the executive committee of the Chicago Section A. I. E. E. was in order. The following were elected: chairman, D. W. Roper, to serve one year; secretary, E. W. Allen, to serve one year; and R. H. Rice, member of the committee, to serve three years.

President Ralph D. Mershon was then introduced, and spoke in a general way of the advantages and benefits derived from these joint meetings of engineering organizations.

The next joint meeting of the Chicago Section A. I. E. E. and the Electrical Section of the Western Society of Engineers was held on May 26, with about 75 members attending. A paper on "Cost Systems in Electrical Contracting" was presented by Mr. Leo Dolkart, engineer of the Tri-City Railway Company, Moline, Illinois, and was followed by a discussion by a number of the members.

Cleveland

The annual dinner of the Cleveland Section was held at the Cleveland Athletic Club on May 19, with 52 members and guests present. Chairman E. J. Edwards presided.

Hon. Newton D. Baker, mayor of Cleveland, was the speaker of the evening, and discussed in an interesting way the relations of the engineer as a citizen under the new municipal charter to be voted upon July 1.

The question of Section participation in Institute affairs was discussed by Messrs. Wallau, Dates, Dingle, McNeice, and Chairman Edwards.

Co-operation with the Cleveland Engineering Society was urged by Professor Dates, and after discussion, the secretary was instructed to request Mr. Eastwood, chairman of the program committee, to endeavor to arrange several joint meetings during the coming year.

The Hon. C. D. Friebolin, chairman of the Judiciary Committee of the State Senate, spoke briefly upon the work of that committee. Following this, the retiring and incoming officers were called upon for short speeches.

After votes of thanks to Mayor Baker and to the retiring officers of the Section the meeting adjourned.

Detroit-Ann Arbor

A meeting of the Detroit-Ann Arbor Section was held in Ann Arbor, Michigan, on May 24, with a total attendance of 18. Secretary Ray K. Holland presided. Mr. H. W. Young, president of the Delta-Star Electric Company of Chicago, presented a paper on "Outdoor High-Tension Substations," illustrated with stereopticon views of various stations and types of construction. A general discussion followed.

Indianapolis-Lafayette

The May meeting of the Indianapolis-Lafayette Section was held in the electrical department lecture room at Purdue University, Lafayette, Tuesday evening, May 6. Vice-Chairman C. F. Harding presided. The speaker was Mr. M. Luckiesh, research physicist of the National Electric Lamp Association.

Mr. Luckiesh spoke on the subject "The Importance of Direction, Quality, and Quantitative Distribution of Light in Illumination," illustrating his talk with a large number of lantern slides, and, by means of a demonstration cabinet, showing the effect of different combinations of colors. He also discussed the effects that could be produced by different methods of illuminating pictures and statuary, demonstrating within the cabinet the methods as discussed.

The talk was open to the public and was enjoyed by many ladies interested in art, as well as an unusually large attendance of members and students.

A special party of 15 members and friends residing in Indianapolis attended the lecture and returned home afterwards in a special car.

The attendance was approximately: Institute members, 20; students, 50; visitors, 30.

Los Angeles

The Los Angeles Section held a meeting on May 27, at the Hotel Hollenbeck, which was attended by 33 members and visitors. Chairman George A. Damon presided.

A paper was presented by Mr. R. W. Sorensen, on "Some Values of Wave Form Analysis." The following members took part in the discussion of the paper: Messrs. J. H. Montgomery, E.

Woodbury, C. E. Howell and R. E. Cunningham.

Madison

A meeting of the Madison Section was held on June 5, in the engineering building of the University of Wisconsin. Secretary F. A. Kartak presided, and the total attendance was 14. Professor Edward Bennett was elected chairman for the ensuing year. The offices of secretary-treasurer and member of the advisory board were not open at this time, election to these offices having been made last year.

Mr. F. J. Mayer presented a paper on "Standards of Telephone Service," which elicited a thorough discussion of facts connected with the study of telephone traffic.

Mexico

The Mexico Section held a meeting on June 5 in Mexico City, which was attended by 18 members and 2 visitors. Chairman H. S. Foley presided. The Section voted to invite the Mexico Mining Institute to attend the July meeting of the Section and participate in the discussion of a paper on "Electric Hoisting and Electricity in Mining."

The paper of the evening was then presented by Mr. A. E. Reynolds, on "Electric Automobiles and Storage Battery Street Cars."

The next meeting of the Mexico Section was held on July 10, preceded by the usual dinner, at the Restaurant Gambrinus. The total attendance at the meeting was 29, and Chairman H. S. Foley presided.

The paper of the evening was presented by Mr. Kennet J. Girdwood, of Pachuca, on "Electric Hoisting and Electricity for Mining." Mr. Girdwood's paper was very practical in its treatment of the subject, covering the use of electricity in mines under the conditions prevailing in Mexico. He discussed three types of hoisting installations, those driven by slip-ring induction motors, those driven by direct-current power derived from motor-generator sets, and those driven by direct-current motors, power for which is obtained from flywheel motor-generator sets. The speaker recommended the first system for installations requiring less than 500 h.p., and the third system for larger hoists which operate continually.

Speaking of electrically operated air compressors, Mr. Girdwood said that in almost every mine in Mexico the compressor installed is 100 per cent larger than that necessary for the number of drills actually in use, because of the free use of compressed air by the miners for blowing out smoke from the blasting and because of the agreeable cooling effect the expanding air had on them.

After taking up electric pumping, electric haulage on the surface and underground, and electric blowers for ventilation, Mr. Girdwood turned to the subject of underground electric lighting. The Mexican miners have had a fondness for candles used to light mines, because they furnished an easy means of warming up their tortillas underground and of lighting their houses cheaply, and in some of the large mines a ton or more of candles is consumed each month. When electric lighting has been installed there has been a considerable loss of lamps through breakage due to blasting, and theft, so that electric mine lighting is almost entirely restricted to main tunnels, passage ways and shaft bottoms, but its use is increasing.

The paper was followed by a thorough discussion by the members.

Milwaukee

The regular joint meeting of the Milwaukee Section of the A. I. E. E. and the Engineers Society of Milwaukee was held June 11 at the Plankinton House. Chairman T. E. Barnum presided. Officers were elected for the coming year. Mr. L. E. Bogen was elected chairman, and Mr. A. J. Goedgen was elected secretary.

Professor Carl E. Pray gave a talk dealing with the Constitution of the United States.

Preceding the business meeting and the talk of the evening the annual dinner was served. There were about 60 in attendance.

MINNESOTA

The Minnesota Section held its June meeting on the 21st, the meeting taking the form of a trip of inspection through the power plant and twine factory of the new Minnesota State Prison at Stillwater.

Mr. Charles L. Pillsbury, consulting engineer of the State Board of Control, personally conducted the tour. The party of 25 members and 15 visitors left St. Paul early in the afternoon, and upon their arrival at the prison were briefly addressed by Warden Wolfer, who presented statistics of the magnitude of the twine manufacturing operations at the present time. The members were then taken through the new power plant, cell room and twine factory.

PITTSBURGH

The Pittsburgh Section held a meeting on June 19, in the rooms of the Engineers Society of Western Pennsylvania. Chairman E. L. Farrar presided, and there was a total attendance of 75.

Mr. Guy P. Thurber delivered a lecture on "Automatic Train Control." Mr. Thurber introduced his subject by presenting figures of the enormous cost, in human life and in money, of railroad accidents in the United States. In the year 1911, according to the Bureau of Railway News and Statistics, the railways in this country paid, for injuries to persons, damage and loss, $59,958,493. Mr. Thurber said that analysis of the accidents causing this tremendous outlay shows that 65 per cent of them could have been prevented by the use of automatic control on trains.

A prominent railroad official was quoted as saying that 90 per cent of railroad accidents are caused by the failure of the human element. The automatic control system, said Mr. Thurber, will prevent most of these accidents by removing the human factor in emergency conditions. That such a system is practical is shown by the Interborough subway in New York, in which a form of mechanical trip has been in constant service for eight years, during which time 1,664,516,822 passengers have been carried without a single fatality due to train accidents, with trains running at from 40 to 50 miles per hour, at intervals as short as one minute, and even 43 seconds.

Ever since automatic signals have been in successful operation there has been an effort on the part of signal engineers to devise some way of successfully transmitting the signals into the cab of the locomotive and in that way have a means of automatically controlling a fast-moving train whenever it approached a danger zone.

The ideal system operates on what is known as the closed circuit principle, so that any error in its operation will be on the side of safety. The system must be included in the circuits which control the signals. Its movements must be coincident with the movements of the signals. Any failure of the circuits or mechanism must cause it to be drawn by gravity to the stop or danger position.

The system described by Mr. Thurber complies with these requirements and has been developed by a number of Pittsburgh engineers and signal men who have spent a great many years working on problems of this kind.

Since October, 1911, the United States Government engineers have been in close touch with tests and trials under service conditions, during all seasons of the year and under all kinds of traffic conditions, from the high-speed express train to the heavy freight train, on the main line of the Pennsylvania Railroad.

This system has also been tried out on one of the lines of the Pittsburgh Railways Company, with great success.

The system, as stated before, is actuated in connection with the signal block system, and by means of electro-pneumatic control of the air brakes of either the engine or electric motor cars.

A number of slides were shown by Mr. Thurber, illustrating various features of the system, such as the brake valve, magnet valve, relay, battery and other essential parts. In the discussion which followed, many questions were asked concerning the system, and answered by Mr. Thurber.

San Francisco

The regular monthly meeting of the San Francisco Section was held on May 23 in the hall of the Native Sons of the Golden West. Mr. C. L. Cory presided. Mr. W. R. Birt of the Southern Pacific Railroad Company presented a paper on "Multiplex Telegraph and Telephone Circuits" which brought out a keen discussion by engineers of the local telephone company.

Prior to the meeting an informal dinner was participated in by about ten members at Jules Restaurant on Market Street. The total attendance at the meeting was about 40.

Schenectady

The annual dinner and the 130th meeting of the Schenectady Section was held at the Mohawk Golf Club on the evening of May 27. The guests of the evening were Mr. Ralph D. Mershon and Mr. C. O. Mailloux. After a very enjoyable dinner, short speeches were made by the following: Messrs. John B. Taylor, D. B. Rushmore, C. L. Clarke, Ralph D. Mershon, H. M. Hobart, C. O. Mailloux, H. W. Peck, L. T. Robinson, W. B. Potter and Joseph Lyons. Mr. John B. Taylor, chairman of the Section, was toastmaster.

This annual dinner marked the close of the season's activities of the Schenectady Section, which has had a very successful year. The total membership of the Section is 642. Seventeen meetings have been held, with an average attendance of 260.

Spokane

The fourth meeting of the Spokane Section was held May 20 in the Spokane Hotel, following an informal dinner. Mr. J. B. Fisken, chairman of the Section, presided. The attendance was 56 all told. This being the last meeting of the year, the following officers were elected to take office in the fall: chairman, Mr. J. B. Fisken; vice-chairman, Mr. J. W. Hungate; secretary-treasurer, Mr. H. B. Pierce; executive committee, Messrs. S. E. Gates, C. F. Uhden, L. N. Rice, V. H. Greisser.

Following the election of officers, a paper was read by Mr. Ray Plank of the Home Telephone Company, entitled "Small Magnet Winding, Theory and Practise." This paper was discussed by Messrs. Robinson, Benson, Corbett and others.

A paper was next read by Professor H. V. Carpenter, entitled "An Exact Formula for Determining the Regulation of Long Transmission Lines," and discussed by Messrs. Hawes and Corbett.

The final paper of the evening was by Mr. R. F. Robinson, on "Transposition of Telephone Lines." This paper was discussed by Messrs. Plank, Benson and Daniels.

Although no regular meetings are to be held during the summer months, it is planned to arrange visits by the Section to various plants of interest in and around Spokane.

Toledo

The Toledo Section held a meeting at the Toledo Commerce Club, on June 5, which was attended by 19 members and visitors. Chairman George E. Kirk presided.

Professor F. C. Caldwell of the Ohio State University addressed the meeting on "Some Notes upon the Transmission, Distribution and Sale of Electrical Energy." Professor Caldwell worked out on the blackboard some original problems in transmission formulas. Lantern slides of the university laboratories were also shown. A discussion followed, which was participated in by many of those present.

The Toledo Section held an election in June to choose officers for the coming year, the voting being conducted by mail. The officers elected are as follows: chairman, George E. Kirk; vice-chairman and program committee, M. W. Hansen; secretary-treasurer, Max Neuber; membership committee, A. W. Little; executive committee, Emil Grah.

Past Branch Meetings

University of Arkansas

On May 14 the University of Arkansas Branch elected officers for the year 1913–14, as follows: chairman, S. S. McGill; secretary, M. B. Roys; treasurer, A. J. Collins.

University of Cincinnati

A meeting of the University of Cincinnati Branch was held on June 3, when the constitution proposed by the committee at the last preceding regular meeting was ratified and adopted. The election of officers for the next school year was then held, resulting as follows: chairman, John H. Stewart; first vice-chairman, A. C. Perry; second vice-chairman, Edison Cherrington; secretary, Clay M. Strait.

A paper was then presented by Mr. F. W. Willey of the Triumph Electric Company, on "Special Features of Direct-Current Motors."

Lehigh University

The April meeting of the Lehigh University Branch was held at South Bethlehem on April 25.

The entire evening was devoted to a study of the Cottrell process for the electro-deposition of smoke, dust and fumes, by Professor W. S. Franklin, assisted by Mr. Linn Bradley of the University of Minnesota. Mr. Bradley is at the head of the Research Corporation of New York and is well acquainted with the originator of the process.

The Cottrell process is an electrolytic means of disposing of injurious gases given off by plants and minerals and also makes possible the recovery of valuable materials from stack gases. The apparatus consists essentially of a long tube or group of tubes containing at their axes a wire conductor. When the gases are blown through the tubes a specially designed generator sets up a high potential between the wire and the tube, causing the deposition of suspended matter.

The process was well illustrated by an experimental apparatus consisting of a glass tube containing two fine wires excited from a friction machine. Smoke or fumes blown into the tube disappeared immediately when the circuit was closed.

Many slides showing the application of the process were thrown on the screen and each picture was explained in detail by Mr. Bradley. A large number of the slides were taken at a cement plant in California which uses the Cottrell process for disposing of the dust in stack gases, thereby saving the orange groves in the vicinity.

The final meeting of the Lehigh University Branch, for the year 1912–13, was held in the physics lecture room on May 23.

Officers of the Branch for the coming year were elected as follows: president, W. B. Todd, 1914; vice-president, J. S. Gemmel, 1914; secretary, G. Forster, 1914; treasurer, H. D. Baldwin, 1914. For the Wireless Club, connected with the Branch, the following officers were elected: president, Mr. Brockman, 1915; secretary, Mr. Andrews, 1916; treasurer, Mr. Glass, 1915.

Mr. D. M. Petty, of the Bethlehem Steel Company, was introduced as the speaker of the evening. Mr. Petty spoke on "The New Electrical Developments at the Bethlehem Steel Works." He gave a short account of the difficulties encountered by the electrical department since 1909 and the manner in which they were overcome. On account of the great demand for electrical power several years ago it was necessary to enlarge the power plant as quickly as possible, thus making a large portion

of the works dependent upon the dynamos. An unexpected break-down made it necessary to shut down this part of the works for some time. This led to the introduction of a system of storage batteries which could be thrown in when an accident occurred in the power plant.

Mr. Petty also gave a brief talk on the new electric furnaces which are at present only an experiment at the works. He further described at length many more of the electrical devices which are being installed, including means for purifying the blast furnace gases and methods for regulating the fields on the motors used in the rolling mills.

Ohio State University

The Ohio State University held an election of officers for the coming school year on May 19. The following were chosen: president, L. R. Yeager; first vice-president, Howard Bryan; second vice-president, W. H. Noble; third vice-president, Robert B. Criswell; secretary-treasurer, John M. Strait; corresponding secretary, Deane M. Richmond; sergeant-at-arms, C. W. Abbott.

University of Oklahoma

The University of Oklahoma Branch held its last regular meeting of the school year on June 4. The program consisted of the annual retiring address of the chairman, D. E. Renshaw, and also an explanation of some lantern slides of the Wagner Electric Manufacturing Company's plant in St. Louis, by Leo H. Gorton.

The following officers were elected for the ensuing year: R. D. Evans, chairman; R. W. Stinson, vice-chairman; L. J. Hibbard, secretary; H. Livergood, treasurer.

University of Oregon

The University of Oregon Branch held a meeting on March 11, when Mr. M. H. Douglass spoke on "The Engineer's Library and Card File."

At the meeting of the Branch on April 8, Mr. Alvin Myers presented a paper on "The Development of a Water Power."

A meeting of the Branch was held on May 13, when nominations of officers for the coming year were made.

The following officers for 1913–14 were elected at a meeting of the Branch on June 4: chairman, C. R. Reid; secretary, C. H. Van Duyn; executive committee, Clyde Pattee, Ray Giles and P. L. Morden.

Rhode Island State College

The last monthly meeting of the Rhode Island State College Branch for the college year was held June 4.

The Agricultural Club attended the meeting, at which a paper was presented by L. A. Whittaker, 1914, upon "Applications of Electricity on the Farm."

University of Washington

A meeting of the University of Washington Branch was held May 22, at which senior thesis subjects were discussed. Mr. M. L. Jones presented a paper on the "Construction of a Direct-Current Lifting Magnet." Mr. H. Bowen presented a paper on the "Test of the Lake Union Power Plant" by Mr. H. O. Blair and himself. It was illustrated with lantern slides. Mr. E. R. Perry showed some oscillograms taken by Mr. George Tripple and himself on the transmission systems of the Puget Sound Traction, Light and Power Company. Mr. R. Coy spoke on "The Construction of a Magnetic Brake for Laboratory Testing." Mr. F. B. Post spoke on "An Electric Still for the Distillation of Wood Products."

On May 27 a meeting of the Branch was held for the election of officers for the coming year. Mr. A. P. Newberry was elected chairman and Mr. Charles A. Stanwick was elected secretary. Mr. L. F. Curtis was chosen as the faculty member on the executive committee.

Personal

Mr. E. W. P. Smith has been engaged under the direction of Mr. E. P. Roberts in the preparation of a "Preliminary Report on the Electrification of Steam Railroads in Cleveland." This report was recently transmitted to Mayor Baker of Cleveland.

Mr. Theron Brown has resigned from the Station Construction Division of the Commonwealth Edison Company, Chicago, Ill., to accept a position in the O. and M. Hydroelectric Section of the Pacific Gas and Electric Company, at San Francisco, Cal.

Mr. William McClellan, who resigned a short time ago as Chief and Engineer of the Division of Light, Heat and Power of the Public Service Commission of the Second District, State of New York, has been retained to assist the President of the Buffalo General Electric Company. Mr. Mc Clellan will also retain his consulting engineering office at 141 Broadway, New York. Mr. McClellan was educated at the University of Pennsylvania and is a member of the Council of the University of Pennsylvania Club of New York City, and president of the Associated "Pennsylvania" Clubs, an organization of the alumni associations of the University of Pennsylvania in all parts of the world. He is a member of the Railroad Club, and the Engineers' Club, of New York City, and the University Club of Albany. He is a Fellow and Manager of the American Institute of Electrical Engineers and a member of the American Society of Mechanical Engineers. He is a director of the Automatic Train Stop Company and of The Campion McClellan Company, engineers and constructors, with offices at Philadelphia.

Mr. William Spencer Murray, chief electrical engineer of the New York, New Haven and Hartford Railroad Company, retired from that position on May 1 and has engaged with Mr. E. H. McHenry in consulting and constructing engineering work. They have opened an office in the Second National Bank Building, New Haven, Conn., whence they will direct all the new electrification work of the New York, New Haven and Hartford Railroad Company as its consulting engineers. Mr. Murray, who was born at Annapolis, Md., August 4, 1873, is a graduate of Lehigh University, and from the time of his graduation in 1895 up to 1901 was in the employ of the Westinghouse Electric and Manufacturing Company. He resigned from the latter company to engage in consulting engineering work in Boston, Mass., and when in 1905 the New York, New Haven and Hartford Railroad Company decided to electrify its New York division Mr. Murray was appointed electrical engineer of the company. An exhaustive analysis and comparison of electric railway systems led him finally to the conclusion that the single-phase system possessed the greatest merit for the proposed electrification, and his recommendation in its favor was adopted. He afterward made a most valuable contribution to the subject of the alternating-current single-phase railway in a paper before the American Institute of Electrical Engineers in December, 1908. Mr. Murray is a member of the Engineers' Club of New York and of the Graduate Club of New Haven. He is a Fellow and Vice-President of the A. I. E. E.

Abstracts of Proceedings of Foreign Engineering Societies

Elektrotechnische Verein (Berlin)

Meeting of April 22, 1913

I. Report of the paper of Professor Breisig, on "A Single Statistical Case of Energy Consumption in a Household." The speaker took in his house regular readings both of the electric meter (illumination) and the gas meter (cooking), and, on the basis of these readings, made calculations as to the probable energy consumption and its

distribution during the day, in case of the introduction of electric cooking. He comes to the conclusion that, if the current for cooking be metered and paid for at the usual rates, cooking by electricity would prove to be considerably more expensive than by gas. But if the current be rated at the "double tariff" or the so-called "Potsdam tariff," the total expenditure for current for light and cooking would not exceed what is spent now for electricity for illumination, and gas for cooking.

II. Report of the paper of Dr. Burstyn, on "A New Process for Extinguishing Electric Arcs, and its Application in Connection with Circuit-Breakers and Interrupters." The process consists essentially in supplying to the break arc, while *in statu nascenti*, high-frequency currents, which are taken from an oscillating circuit consisting of a suitable condenser and short connecting wires, no choke coils being required. By the superposition of the high-frequency current upon the direct current of the break arc at a certain moment the current is made artificially to pass through zero values; the arc then goes out, provided however that the contacts are made as a "blow-out spark gap," *i.e.*, provide good means for carrying off of heat. It was shown how a current of about 40 amperes and 440 volts can be interrupted with almost no sparks by means of a by-path of only a few millimeters. The speaker showed several applications of his method, *e.g.*, interrupters for spark coils, relays, and time and flash switches for advertising devices.

Meeting of May 6, 1913

I. Report of the paper of General Secretary Dettmar on "German Heavy Current Installations and their Safety."

It is first shown that hitherto the safety of operation of electric installations has been insufficiently secured, and a way to do it right is pointed out. The influence is considered of various important factors which must be absolutely taken into account, and it is shown particularly that no precise idea as to the installation may be formed without knowledge of its extent. For this purpose an extensive collection of information as to the applications of electricity in Germany is presented, and compared with the available data as to accidents. It is shown by this comparison that the safety of electric plants in Germany has been all the time improving, and is continuing to do so. It is further shown that the number of accidents and fires which are prevented by the use of electricity is considerably larger than the number of those produced by electricity. The importance of electricity as a means of accident prevention is thereby fully established.

Société Internationale des Electriciens

Meeting of April 17, 1913

I. Report on "High-Tension Continuous-Current Traction," by M. Gratzmuller. Historical sketch of conditions which have brought engineers to consider high-tension continuous-current traction: introduction in America of continuous-current traction at 500 volts (Ward Leonard), the rolling stock being now practically identical in all large enterprises; extension of the distance to be operated turns attention to three-phase current (de Kando); then the inconvenience of three wires brings the constructors to single-phase (Lamme). Cost of d-c. traction with higher voltages.

(1) *Production of high-tension continuous current.* (a) Generating stations at a distance from the traction lines; use of three-phase high-tension currents, then motor-generators, cascade converters of the Leblanc-Arnold type, static transformers and synchronous converters. The motor-generator is too expensive; the cascade converter is of interest only when the frequency is high, say about 50 periods, and the voltage below 12,000 volts, with a sufficiently high power. The solution

of the problem by means of synchronous converters and transformers is the most common, with the rotors eventually in series. (b) The mechanical energy is directly transformed into electric, by connecting hydraulic turbines with dynamos wound for 1500 volts. If steam turbines are used, the way generally used now is still to pass through the three-phase current.

(2) *Contact line.* The intensity is greater, and the weak point is that with 3000 volts and 500 amperes only 1500 kw. can be transmitted. With the same current there is a smaller difference of potential in the return rail; inconvenience of electrolysis effects.

(3) *Motors.* Rational calculation of a motor; uniformly distributed compensation, commutating poles; weight; necessity of increasing more and more the peripheral speed, and of cooling the motor by ventilation; improvement of gears.

(4) *Auxiliary apparatus and regulation.* Low-tension current for operating auxiliary apparatus can be obtained by means of a dynamotor or motor-generator. The variations required for the multiple control, starting, governing and braking are obtained by means of a step-up-step-down transformer or rotary apparatus. This solution has become practical owing to increase in peripheral speed and to ventilation. Considerable simplification of apparatus with economy in power.

(5) *Description of the existing installations.*

II. "The Problem of Railway Electrification in the United States," by H. Parodi, Engineer-in-chief of Department of Electricity of the Orleans Railroad Company. Mr. Parodi recalls at first the general conditions of steam railroad operation in the United States, and then shows that although on electrically operated tramways the first costs of installation have gone up to 330,000 francs average per kilometer, the average tariff of 24.1 centimes per passenger permits of obtaining an average coefficient of operation of 60 per cent, with a cost of about 0.50 fr. per car-kilometer. To obtain a similar result by substituting electric power for steam on suburban lines with a tariff of 6 centimes per passenger-kilometer, the electrification must be limited to lines having a density of traffic of about 20 passengers per car, and a kilometric return of about 100,000 francs per kilometer of line. The cost of electrification varies from 100,000 to 200,000 fr. per kilometer, single track, in accordance with the system adopted: 100,000 fr. for d-c. lines from Camden to Atlantic City, and 200,000 fr. for single-phase lines, entrance to Boston, now under consideration by the N. Y., N. H. & H. R.R. The operation costs on electric railways vary with the system of traction adopted and density of traffic. With direct current they are about 0.50 fr. per car-kilometer on the West Jersey & Seashore Railroad, and 0.75 fr. on the Long Island Railroad. They are much higher with single-phase current than with direct current; for tramway lines this difference is usually about 0.10 fr. per car-kilometer. On the New York suburban lines the electric traction costs of operation in 1911 were as follows:

On the New York Central, with direct current, for regular service with 47 locomotives, 2000-h.p. type, and 137 motor cars, 480-h.p., 2,891,435 fr.

On the N. Y., N. H. & H. R.R., with single-phase alternating current, 47 locomotives, 1000-h.p., and 4 motor cars, 600-h.p., 4,521,267 fr.

The nature of the current affects also the system of operation, and it is much easier to obtain the power necessary to drive motor-car trains of varying make-up with direct current than with single-phase alternating current. Mr. Parodi shows that it does not appear possible that, at least at the present time, electricity can compete with traction by steam: owing to the use of superheat, the consumption of coal per kw. at the drawbar of the steam locomotive is now only about 1.6 kg.

The nature of the current and the

method of transmitting power to the locomotive axle have a great influence on the cost of locomotive maintenance. On the N. Y., N. H. & H. R.R., with single-phase locomotive and transmission by gears and flexible coupling, the maintenance cost was in 1911 0.22 fr. per kilometer per locomotive of 1000 h.p. On the Pennsylvania R.R., with direct current and connecting rod transmission the cost was 0.215 fr. per kilometer per locomotive of 2000 h.p.; on the New York Central, with direct current and direct connection, the cost was 0.11 fr. per kilometer per locomotive of 2000 h.p.

The method of transmission to the locomotive axle has an important bearing on the running of the locomotive, and experiments made by the Pennsylvania Railroad on a special track provided with means for registering shocks received by the rails have shown that the use of a locomotive with a high center of gravity and connecting rod transmission gives better results as far as rolling is concerned than other systems of transmission. Mr. Parodi shows further that for work in mountainous regions better results may be obtained with electric traction than with steam, especially owing to the possibility of constructing high-power complete-adhesion locomotives. The increase in cost of operation as a function of the grade is much slower in the case of electric traction than with steam, so that the substitution of one system of traction for another appears to become advantageous from a certain critical grade up.

III. "On the Projects of Electrification of the Southern Railways Company," by Mr. Jullian. The Southern Railways Company has decided to electrify its Pyrenean section in order to profit by the advantages of electric traction on steep grade lines and by the assistance promised to it by the State for the construction of shops and equipment to be used in connection with the lines already in operation and those to be built. Single-phase alternating current has been selected, at a frequency of 16⅔, and 12,000 volts for the working lines, and 60,000 volts for transmission lines. The lines in operation now being electrified have a mileage of about 400 km., including 112 km. of double-track lines, while the lines to be built are to have about 300 km., including the two trans-pyrenean lines. Four hydraulic installations, of 18,000 to 20,000 h.p. each, will produce all the current required, to be distributed at 60,000 volts to five substations, by a double line of aluminum cables. These five substations will be equipped for 2500 kv-a., but can deliver up to 5000 kv-a., the current, at 12,000 volts, to be sent to the working lines, of the simple catenary type. An auxiliary group is also provided. The cables, both transmission and working line, on single-track lines, are supported on girder poles made of old rails held together by old gusset plates; on double-track lines the poles are made of iron girder poles. The Southern Railways Company will also electrify the line from Perpignan to Villefranche, on which preliminary tests with single-phase traction were made; on that line single-phase current at 12,000 volts and frequency 16⅔ will be used, furnished directly by a special station of 4000 h.p., the line being of the simple catenary type, with iron girder poles. The rolling stock will comprise locomotives of 1800 h.p-hr., and motor cars of 500 h.p-hr. The Department of Posts and Telegraphs has raised some difficulties in connection with disturbances produced in the operation of its transmissions by the traction current, but everything tends to the belief that these difficulties will be overcome.

Meeting of May 7, 1913

I. "Biological Phenomena and Electrical Apparatus," Presidential address of Mr. Daniel Berthelot. A large number of cold-blooded animals react with extreme sensitiveness even at feeble electric excitations, *e.g.*, the snail with respect to telephone currents,

the frog to electric undulations, etc. The study of physiological mechanisms familiar to the physicists of the eighteenth century (Cavendish, Volta, Galvani, etc.) can still be of use; Branly has pointed out the analogies between the discontinuous conductivity of a filings coherer on the one hand and nerve fibre and neurons on the other. The animal machine differs from the artificial machine in the preponderant part played in the former by capillary energy, increase in power being obtained by repetition of parts and not by raising the potential or increasing the dimensions. In this respect Lippmann's electrocapillary motor approaches the natural mechanisms. The same was the case with the Voltaic pile, which revolutionized the science of electricity while Volta was searching for a way to imitate artificially the electric eel. Even today, could one but guess the secret of its mechanism, the study of the glowworm might revolutionize the entire industry of light production.

II. "Tests for Determination of Properties and Specification of Insulating Fabrics." Investigations made by the Central Laboratory of Electricity, by H. Bureau. These tests are a particular application of the general program, prepared by the First Section, for the investigation of insulating materials, to the case of fabrics treated with insulating materials. They comprise a systematic series of tests having for their purpose the determination of the essential characteristics of the fabrics, as well as the changes which their properties undergo when placed in the different conditions of industrial practise.

Preliminary tests: homogeneity; influence of small pressures and duration of electrisation. Electric tests: dielectric rigidity and insulating resistance, specific inductivity, losses; influence of heat, 70 and 120 deg. cent., humidity, oil, high compression and folding, on the electrical properties of the fabric. Mechanical tests: tension, shearing, bending; influence of heat and humidity on mechanical properties. Physical tests: change of appearance and flexibility under the influence of heat and humidity; penetration of water, steam, cold oil, oil at 70 deg. cent., inflammability by conduction, radiation, and arc. Chemical tests: content of insulating material, water of impregnation and acid; action on copper, iron and brass. Tests for aging: prolonged exposure to air; alteration artificially produced by the action of silent discharges. In order to give to these tests a really practical character, it was endeavored as a general rule to make them with the simplest apparatus and by the simplest methods possible. By experimenting with a large number of test pieces, results were obtained which permitted the differentiation of the various fabrics and the determination of the effects produced on them by the action of atmospheric agents and various influences to which they are exposed in practical operations.

III. "X-Rays (Medical Applications)," by Dr. Henri Beclere, Assistant in Radiotherapy at the St. Antoine Hospital. Thanks to the investigations of engineers and the genius of designers, guided by the requirements of everyday use, physicians have now at their disposal electrical machinery which permits them not only to make more precise certain often very difficult diagnoses, but also to treat a considerable number of affections which have hitherto resisted the methods of common medicine. In the new science of radiology discoveries have succeeded one another with remarkable rapidity, and one may say that the instruments which we have now at our command are very near perfection. They answer all requirements, and help to extend the application of Roentgen rays to all the branches of medical art. The radiography which for a long time confined itself to the examination of skeleton lesions, has now gone beyond those limits, so that the former method of investigation, while of very great im-

portance in itself, is relegated to far less important place generally. The intestines are now every day investigated by Roentgen rays, and furnish information of the greatest importance. The stomach, kidneys, heart, lungs, liver, etc., are disclosed to us either directly, or by special devices, and no medical examination of those different organs is complete until supplemented by a radiological examination. In the domain of therapeutics, owing to the perfection in the handling of the apparatus and in the notions of measure, X-rays occupy nowadays a very important place. Surface lesions are not the only ones now treated by radiotherapy, and there are many circumstances in which deeply located tumors may benefit by this method of healing. The above was illustrated by the speaker by means of casts from the radiography museum of the St. Antoine Hospital, and by slides.

IV. "Variations of Residual Magnetism in Steel Magnetized while Cold, as a Function of Temperature," by Mr. Felix Robin. In these experiments it was sought to determine for each kind of steel the process of *demagnetization* as it occurs when bars of steel magnetized while cold are subjected to successive heating and cooling away from a magnetic field. In the first place these tests were to constitute a metallurgical investigation, interesting in that it supplies information as to the nature of a piece of steel without altering its shape. It was therefore sought to bring out the characteristic peculiarities of the curves of demagnetization under the action of heat, and spontaneous remagnetization on cooling, without paying much attention to the absolute value of the initial magnetization. If these investigations had had purposes in connection with electromagnetic applications, it would have been necessary to start with different initial (while cold) magnetizations, and, in particular, with complete saturation. In this investigation it was considered sufficient to start in each test with a value in the neighborhood of complete saturation. From the point of view of industrial applications of electromagnetism, it is believed that the numerical determinations shown in the tests, will answer the following double purpose: (1) to give information as to the nature of a piece of steel by means of an easy and fairly rapid test; (2) to give indications as to the magnetic variations in places often heated and cooled. Perhaps, further, in some of the tests a correlation may be found with the phenomenon known as magnetic aging. In what follows, indications along these general lines will be found as to the results obtained with long cylindrical test bars heated at an average rate of 30 deg. cent. per minute.

Iron. Residual magnetism, very weak, decreases very slowly at heating. The curves of variation of flux present a marked bend towards 100 deg., in accordance with the singular behavior observed in the study of variations of hardness and sonority. From 160 to 180 deg. is manifested a rapid fall of magnetization due to the presence of cementite which is unavoidable in commercial iron and which loses its magnetization at 180 deg., as shown by the experiments of Wologdine. At cooling the magnetization increases slightly, exhibiting the same singularities; succeeding cycles of heating give identical results.

Carbon Steel. The intensity of residual magnetism at 20 deg., the rapidity of its loss at heating, and the position of the bend in the curve corresponding to 180 deg., are characteristic for the carbon content. Tempered steel is distinguished by the rapid fall of magnetization from 100 deg. on, and by its not varying at cooling, so long as the important return points (300 deg.) have not been passed.

Special Steels. Tungsten preserves the fall of magnetism at 180 deg., while chromium does away with it entirely. High-speed steels are characterized by remarkably preserving their magnetism while hot. Nickel tends to suppress the

bend in the curve of demagnetization and to make it approach the curve for pure nickel. Phosphorus and silicon have a special effect. Cold rolling acts in a manner analogous to tempering. Magnetic variations in steels of all kinds depend for the most part on two superimposed actions: the variations in the hardness of iron or of the solid solution which constitutes the steel, and the loss of magnetism proper to the constituents of the steel.

Meeting of June 4, 1913

I. "New Universal Permeameter," by Mr. A. Iliovici. Purpose: measurement of permeability of test pieces cut from sheets of solid steel. Description: the test piece is a parallelopiped with rectangular cross-section; its magnetic circuit is closed by a yoke of soft iron; the test piece carries two coils; one with wire capable of carrying up to 3 or 4 amperes, the other wound with fine wire, to be placed in circuit with a fluxmeter or ballistic galvanometer. On the yoke is wound a coil capable of carrying up to 2 amperes; the fine wire coil is in series with an ammeter or regulating rheostat; the yoke coil is also in series with a rheostat. A second yoke also carries a fine wire coil which may be placed in circuit with a fluxmeter or ballistic galvanometer. The apparatus comprises also an interrupter, a reversing switch which reverses simultaneously the direction of the current in the fine wire coils on the test piece and first yoke, and a commutator for cutting in the fluxmeter or galvanometer. Operation: a current of some convenient strength i is sent through the fine wire coil on the test piece and a second current i' sent through the coil on the yoke and regulated in such a manner that the difference of magnetic potential between two given points is zero. The portion of the test piece between these two points behaves then like a closed magnetic circuit. The zero difference of magnetic potential is marked by the fluxmeter on the second yoke showing no elongation when the currents i and i' are simultaneously reversed. The field in the test piece is $\mathbf{H}=\frac{n\ i}{l}$ where n is the number of turns in the fine wire coil on the test piece, and l the useful length of the test piece. The apparatus is constructed so that $\mathbf{H}=100\,i$. The induction is measured on the fluxmeter on the coil on the second yoke and magnetic fields up to 400 gausses may be used. The results are practically the same as when a ring is used.

II. "Electrolytic Detector with No Auxiliary Electromotive Force," by Mr. P. Jegou. Purpose of investigation: The electrolytic detector, as compared with the crystal detector, already presents the advantage of being sturdy, regular in working, and not easily put out of order. It was therefore of interest to design, in addition, an electrolytic detector that could be used, like a crystal detector, without an auxiliary source of electromotive power. First realization in 1909: at the Congress of the French Association for the Advancement of Sciences the author indicated the principle of a detector in which the inactive electrode (cathode) was an amalgam of mercury and tin. Actual construction: the author has since recognized that the sensibility of a zinc-mercury amalgam is greater than that of an ordinary electrolytic detector, and that it is invariable and stable. The contact of the electrolyte with the two electrodes of different constitution forms a small couple giving a noticeable action in the form of a current opposite in direction to that of a detector with auxiliary poles. The author gives a table of critical tensions at the anode and cathode, which prove the principle of sensibility of the detector with no auxiliary currents.

III. "Bauxite and Electric Furnace," by Mr. G. Flusin. Principle of treatment: bauxite, which is an ore of aluminum hydrate impure, when melted in the electric furnace, takes on, in solidifying, a crystalline structure,

and furnishes a product analogous to emery or corundum, depending upon the proportion of impurities present.

A refining fusion of the impure bauxite with charcoal gives artificial corundum. The impurities, Fe_2O_3, SiO_2, TiO_2, which are more easily reduced than the bauxite, give a complex and dense alloy of the corresponding metals which separates itself from liquid aluminum.

Products Obtained. Corundum: the diverse varieties of melted aluminum (artificial corundum) have abrasive qualities which depends on the composition and process of manufacture of the material. Chemically pure aluminum: interesting experiments were made in the way of electrothermic purification, in order to arrive at an aluminum suitable for the purification of steel. Alloys (silico-aluminum, silico-titanium): obtained from a partial reduction of the constituents of the bauxite, they are used for purification of steel. Aluminum: experiments on total reduction have given a mixture of aluminum and carbide, the latter dissociating at high temperature to give aluminum. Nitrate: in a current of nitrogen, aluminum nitrate has been obtained. Alumina: treated by a soda solution, the nitrate of aluminum gives ammoniac and sodium aluminate which, on decomposing, gives pure alumina suitable for use for manufacture of aluminum, the cost of the latter being reduced by the value of the by-products (Serpek process).

Library Accessions

The following accessions have been made to the Library of the Institute, since the last acknowledgment.

American Electrochemical Society. Transactions. General Index, Vols. I-XX. South Bethlehem, 1913. (Gift of Society.)

American Railway Association. Proceedings of the session held in New York City, May 21, 1913. (Gift of Association.)

American Telegraphy and Encyclopedia of the Telegraph. By William Maver, Jr. New York, 1912. (Purchase.)

Association of Iron and Steel Electrical Engineers. Proceedings of the First Co-Operative Safety Congress. Milwaukee, Sept. 30–Oct. 5, 1912. N.p., 1912. (Gift of Association.)

Bau grosser Elektrizitätswerke. By G. Klingenberg. Berlin, 1913. (Purchase.)

Calculating Rule for the Illumination and Photometric Measurement. By T. Hirobe and R. R. Mitsuda. N.p. n.d. (Gift of Electro Technical Laboratory, Tokyo.)

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Etude sur le Marché du Cuivre. By J. Sainz. Lille, 1913. (Gift of author.)

The Foundations of Alternate Current Theory. By C. V. Drysdale, London, 1910. (Purchase.)

Handbuch der Elektrizität und des Magnetismus. Band IV, pt. 1. By L. Graetz. Leipzig, 1913. (Purchase.)

Instructions for the use of Calculating Rule for the Illumination and Photometric Measurement. By T. Hirobe and R. Mitsuda. N.p. n.d. (Gift of Electro-Technical Laboratory, Tokyo.)

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Michigan Railroad Commission. Annual Report 4th. Lansing, 1911. (Gift of American Electric Railway Association.)

Municipal Engineers of the City of New York. Proceedings, 1912. New York, 1912. (Gift of Municipal Engineers of the City of New York.)

New York City Board of Water Supply. Annual Report 7th. New York, 1912. (Gift of Board of Water Supply.)

New York City Public Service Commission for the First District Contract No. 3 with Interborough Rapid Transit Company. March 19, 1913.

——Contract No. 4 with New York Municipal Railway Corporation. March 19, 1913. (Exchange.)

New York State Department of Labor. Annual Report of Department Bureaus. Vol. I and III, 1911. Albany, 1913.

——Annual Report of the Commissioner of Labor 12th, 1912. Albany, 1913. (Gift of Department of Labor.)

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Die Physikalisch-Technische Reichsanstalt. Funfundzwanzig jahre ihrer Tätigkeit. Berlin, n.d. (Exchange.)

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——To Manhattan Railway Company. Second Avenue, Third Avenue and Ninth Avenue additional tracks.

——To New York Municipal Railway Corporation. Jamaica Line, Liberty Ave. Line.

——Broadway, Fulton St. and Myrtle Avenue additional tracks. (Exchange.)

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Das Schiffahrtsabgabengesetz vom 24 Dezember. 1911. By F. Geigel. Halle a.S., 1912, (Purchase.)

Société Francaise de Physique. Annuaire 1913. Paris, 1913. (Exchange.)

——Procès-Verbaux et Resumé des Communications faites pendant l'annee 1912. Paris, 1913. (Exchange.)

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Southwestern Electrical and Gas Association. Papers to be delivered at the 9th Annual Convention, May 21–24, 1913. N.p. n.d. (Gift of Association.)

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Les Transmissions Electriques d'Energie en Italie. Rapport. Paris, 1911. (Gift of Préfecture de la Seine.)

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Westinghouse Electric & Manufacturing Company. Annual Report, March 31, 1913. New York, 1913. (Exchange.)

Wireless Operators' Pocketbook of Information and Diagram. By L. W. Bishop. Lynn, Bubier Publishing Co., 1911. (Gift of author.)

This is an elementary manual for wireless operators, free from technical language. It has a call list of wireless stations. W. P. C.

GIFT OF AMERICAN TELEPHONE & TELEGRAPH CO.

Electrician. Vols. 30, 36–51. London, 1892, 1895–1903.

Electrical Review. Vols. 11–60. London, 1887–1912.

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Bruce Macbeth Engine Co., Cleveland, O. Gas power advocate. March, 1913.

Central Electric Co., Chicago, Ill. Electron. Vo. 1, No. 4. May, 1913.

Chicago Pneumatic Tool Co., Chicago, Ill. Bull. No. 34L—General pneumatic engineering information. 47 pp.

——Bull. No. 128—Miscellaneous Equipment for pneumatic drills. April, 1913.

——Bull. No. 132—Pneumatic motors and pneumatic geared hoists. April, 1913.

——Bull. No. 133—Cylinder air hoists and jacks. April, 1913.

Dings Electro Magnetic Separator Co., Milwaukee. Bull No. 21—Magnetic separators. 20 pp.

——Bull. No. 22—Magnetic pulleys and pulley type magnetic separators.

Electric Storage Battery Co., Philadelphia, Pa. Chloride accumulator in iron and steel mills. 1909–13.

Electric Weighing Co., New York, N. Y. Electric Conveyor Scales Messiter Patents.

Fairbanks, Morse & Co., Chicago, Ill. Bull No. 25—Catechism on direct current apparatus. June, 1911.

——Bull. No. 35—Catechism on alternating current apparatus. June, 1913.

General Electric Co., Schenectady, N. Y. Bull. No. A4102—Sewing machine motors. April, 1913.

——Bull. No. A4113—Oil switches for small capacity industrial application type F, forms P 3 and P. 6. April, 1913.

——Bull. No. A4114—Central station oil switches type F, form K 21. April, 1913.

——Bull. No. A4116—Isolated and small plant alternating current switchboard panels. April, 1913.

Goulds Manufacturing Co., Seneca Falls, N. Y. Booklet describing various pumps. 18 pp.

Improved Equipment Co., New York. Bull. No. 6—Silica retorts and settings for gas benches. April, 1913.

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Ohio Brass Co., Mansfield, O. Bulletin. April-May, 1913.

Pettingell-Andrews Co., Boston, Mass. Juice. May, June, 1913.

Philadelphia Electric Co., Philadelphia, Pa. Bulletin. June 1913.

Pyrene Manufacturing Co., New York, N. Y. Pyrene Electrical edition. June, 1913.

Sprague Electric Works, New York, N. Y. Cat. No. 521—Sprague flexible steel armored hose.

——Cat. No. 439—Sprague Conduit products.

——Sprague electric equipment for printing machinery. (Pamphlet No. 245.)

Standard Underground Cable Co., Pittsburgh, Pa. Bull. No. 700-1—Outdoor cable terminals. D. O. A. type. 28 pp.

Wagner Electric Manufacturing Co., St. Louis, Mo. Bull. No. 100—Wagner alternating-current rectifier. May, 1913. (Gift of Ray L. Lillibridge Incorporated.)

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UNITED ENGINEERING SOCIETY

Carnegie Endowment for International Peace. Year Book 1912. Washington, 1913. (Gift of Carnegie Endowment for International Peace.)

Kansas Gas and Electric Light Street Railway and Water Association. List of Members. 1913. N.p. n.d. (Gift of Association.)

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Nebraska State Railway Commission. Annual Report 5th. Lincoln, 1912. (Gift of Nebraska State Railway Commission.)

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Patente. Jahres-Katalog XXIV Jahrgang, 1912. Brugg, 1913. (Purchase.)

Report of the Committee appointed pursuant to House resolutions 429 and 504 to Investigate the Concentration of Control of Money and Credit. Feb. 28, 1913. (Gift of House of Representatives.)

OFFICERS AND BOARD OF DIRECTORS, 1913-1914

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(Term expires July 31, 1914)

C. O. MAILLOUX.

JUNIOR PAST-PRESIDENTS.

GANO DUNN.

RALPH D. MERSHON.

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(Term expires July 31, 1914.)

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(Term expires July 31, 1916.)

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B. A. BEHREND.
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(Term expires July 31, 1914.)

TREASURER.

GEORGE A. HAMILTON.

SECRETARY.

F. L. HUTCHINSON.

PAST-PRESIDENTS.—1884-1913.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, Jr., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.

*Deceased.

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RALPH W. POPE,
33 West 39th Street, New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York

LIST OF SECTIONS.

Revised to August 1, 1913.

Name and when Organized	Chairman	Secretary
Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Baltimore........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, Industrial Building, Baltimore, Md.
Boston...........Feb. 13, '03	N. J. Neall	Leavitt L. Edgar, 39 Boylston St., Boston, Mass.
Chicago................1893	D. W. Roper.	E. W. Allen, 1028 Monadnock Building, Chicago, Ill.
Cleveland........Sept. 27, '07	J. C. Lincoln.	R. E. Scovel, American Steel and Wire Company, Cleveland, Ohio
Detroit Ann Arbor.Jan. 13, '11		Ray K. Holland, Cornwall Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	T. W. Behan.	P. H. Haselton, Fort Wayne Electric Works, Ft. Wayne, Ind.
Indianapolis-Lafayette Jan. 12, '12	O. S. More.	Charles A. Tripp, 710 Majestic Building, Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles......May 19, '08	E. R. Northmore.	C. G. Pyle, 914 Hibernian Bldg., Los Angeles, Cal.
Lynn............Aug. 22, '11	W. A. Hall.	E. R. Berry, General Electric Co., Lynn, Mass.
Madison.........Jan. 8, '09	Edward Bennett.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	H. S. Foley,	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
•**Milwaukee**.......Feb. 11, '10	L. E. Bogen.	A. J. Goedgen, Milwaukee Electric Ry. and Lt. Co., Milwaukee, Wis.
Minnesota.......Apr. 7, '02	W. T. Ryan.	Fred G. Dustin, 9 South Fifth St., Minneapolis, Minn.
Philadelphia......Feb. 18, '03	H. A. Hornor.	H. F. Sanville, 1326 Chestnut St., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	E. L. Farrar,	M. C. Turpin, Department of Publicity, W. E. and M. Company, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, 40 Bartlett Ave., Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock,	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
San Francisco.....Dec. 23, '04	H. W. Crozier.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady......Jan. 26, '03	John B. Taylor.	J. A. Dewhurst, Gen. Elec. Co., Schenectady, N. Y.
Seattle...........Jan. 19, '04	J. D. Ross.	M. T. Crawford, 608 Electric Bldg., Seattle, Wash.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
Toledo...........June 3, '07	George E. Kirk,	Max Neuber, Care of Cohen, Freidlander & Martin, Toledo, O.
Toronto..........Sept. 30, '03	F. A. Gaby.	H. T. Case. Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	A. M. Buck.	F. G. Wilson, University of Illinois, Urbana, Ill.
Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, British Columbia Electric Railway Company, Vancouver, B. C.
Washington, D. C.Apr. 9, '03	H. C. Eddy.	C. B. Mirick, 1330 New York Avenue, N.W., Washington, D. C.

Total, 29.

LIST OF BRANCHES.

Revised to August 1, 1913.

Name and when Organized	Chairman	Secretary
Agricultural and Mechanical College of Texas.......Nov. 12, '09	S. E. Bowler.	E. S. Lammers, Jr. College Station, Texas.
Arkansas, Univ. of.......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson,	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	E. M. Richards.	Robert L. Rooke, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost,	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	Clay M. Strait, Univ. of Cincinnati, Cincinnati, Ohio.
Clemson Agricultural College.................Nov. 8, '12	J. H. Kangeter.	H. J. Bomar, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	Robert O. Sewell.	R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, '04	L. E. Sweitzer.	Frank A. Redding, University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	J. W. Spooner.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.......Apr. 15, '03	H.C.Bartholomew	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of...........May 18, '09	L. F. Hatz.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col....Jan. 10, '08	C. A. Leech.	W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ of.........Mar. 18, '08	S. S. Schooley.	A. J. Fecht, Univ. of Kansas, Lawrence, Can.
Kentucky, State Univ. of.Oct. 14, '10	R. B. Pogue.	W. M. Lane, 216 Rose Street, Lexington, Ky.
Lafayette College........Apr. 5, '12	G. P. Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
Lehigh University.......Oct. 15, '02	W. B. Todd.	G. Forster, Lehigh University, S. Bethlehem, Pa.
Lewis Institute..........Nov. 8, '07	Ralph Kilner.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Maine, Univ of..........Dec. 26, '06	Howard O.Burgess	J. Larcom Ober, S. A. E. House, Orono, Maine.
Michigan Univ of........Mar. 25, '04	Ward F. Davidson	Edward A. Roeser, Univ. of Michigan, Ann Arbor, Mich.
Missouri, Univ of........Jan. 10, '03	H. B. Shaw.	E. W. Kellogg, 9 Engineering Building, Columbia, Mo.
Montana State Col.......May 21, '07	Lawrence Wylie.	J. A. Thaler, Montana State College, Boseman, Mont

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Nebraska, Univ of.......Apr. 10, '08	Olin J. Ferguson.	V. L. Hollister, Station A, Lincoln, Nebraska
New Hampshire Col.....Feb. 19, '09	Robin Beach.	Clayton W. Work, New Hampshire College, Durham, N.H.
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	S. B. Sykes.	J. W. Johnson, N. C. College of A. and M. Arts, West Raleigh, N. C.
Ohio Northern Univ.....Feb. 9, '12	George E. Boesger	Harry Restofski, Ohio Northern University, Ada, Ohio.
Ohio State Univ.........Dec. 20, '02	L. R. Yeager.	John M. Strait, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Coll...........Oct. 13, '11	A. P. Little,	J. W. Harvey, 416 Hester Street, Stillwater, Okla.
Oklahoma, Univ of.......Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	Lance Read.	Charles E. Oakes, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	C. R. Reid.	C. H. Van Duyn, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	K. P. Fuhrman.	I. S. Nippes, Pennsylvania State College, State College, Pa.
Purdue Univ............Jan. 26, '03	C. F. Harding.	A. N. Topping, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	S. Irwin Stocking.	Joseph E. O'Connell, 457 N. 8th Street, Terre Haute, Ind.
Rhode Island State Coll..Mar. 14, '13	Harry Webb.	L. A. Whittaker.
Stanford Univ...........Dec. 13, '07	G. O. Wilson.	L. M. Bussert, Stanford University, Cal.
Syracuse Univ..........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.........Feb. 14, '08	J. A. Correll.	Joseph W. Ramsey, University of Texas, Austin, Tex.
Throop College of Technology...............Oct. 14, '10	Ray Gerhart.	R. W. Parkinson, Throop Poly. Institute, Pasadena, Cal.
Univ. of Washington.....Dec. 13, '12	A. P. Newbury.	Charles A. Stanwick, Univ. of Washington, Seattle, Wash.
Vermont, Univ. of.......Nov. 11, '10	Walter L. Upson.	O. Krupp, 65 North Bend St., Burlington, Vt.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	Henry Woodman Clark, A. X. P. House, University, Virginia.
Wash., State Coll of......Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ........Feb. 26, '04	C. E. Wright.	A. S. Blatterman, 45 Lewis Place, St. Louis, Mo.
Worcester Poly. Inst.....Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University.........Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

Total, 47.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

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THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

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Vol. XXXII September, 1913 No. 9

Pacific Coast Convention, Vancouver, B. C., September 9-11, 1913

The Pacific Coast Convention of the A. I. E. E. will be held at the Oddfellows Hall, corner of Hamilton and Pender Streets, Vancouver, B. C., Tuesday, Wednesday and Thursday, September 9, 10 and 11.

Transportation

The usual arrangements for transportation have been made. Members from Idaho, Oregon, Montana, Utah, Washington, California and British Columbia should purchase a first-class full fare one-way ticket to Vancouver, and secure from the ticket agent a standard convention certificate. When this certificate has been signed by the Secretary at the convention the return ticket may be obtained at one-third single fare.

Members from the Eastern States can take advantage of the round trip tourist tickets.

Members from all other than points on the Southern Pacific Railway should purchase tickets between September 4 and 10; from Southern Pacific points tickets may be purchased between August 29 and September 10.

Members holding certificates from other than Southern Pacific points will be required to present them for return transportation between September 10 and 15; certificates from Southern Pacific points will be honored any time between September 8 and 17.

Tickets for the return journey will be issued by the same route only as used on the going journey, and will be good for continuous passage only.

Program

The following program has been arranged:

Monday, September 8

Afternoon: Office open for registration, Oddfellows' Hall, corner Hamilton and Pender Streets.

Tuesday, September 9

Morning: Office open for registration.

Opening meeting. Address of welcome by Premier of British Columbia, followed by paper and discussion: *Effects of Ice Loading on Transmission Lines.* By V. H. Greisser.

Afternoon: Paper and discussion: *Mountain Railway Electrification.* By A. H. Babcock.

Automobile and car trips, seeing Vancouver, for the ladies of the party.

Evening: To be left free for theaters and private entertainment.

Wednesday, September 10

Morning: Paper and discussion: *The Gulf of Georgia Submarine Telephone Cable.* By E. P. LaBelle and L.P. Crim.

Afternoon: Paper and discussion: *A Modern Substation in the Coeur d'Alene Mining District.* By J. B. Fisken.

Automobile drive to Capilano Canyon for the ladies.

Evening: Illustrated lecture.

THURSDAY, SEPTEMBER 11

Morning: Paper and discussion: *Logging by Electricity.* By E. J. Barry.

Afternoon: Paper and discussion: *Notes on Oil Circuit Breakers for Large Powers and High Potentials.* By K.C. Randall.

Automobile drive for the ladies around Stanley Park and Marine Drive, followed by tea party.

Evening: Banquet.

FRIDAY, SEPTEMBER 12

Rail and lake excursion to new generating station of the Western Canada Power Company at Stave Falls.

SATURDAY, SEPTEMBER 13

Boat excursion to new generating station of the British Columbia Electric Railway Company at Lake Buntzen.

HOTELS

" Vancouver "

Single room $2.50 & up; with bath $3.00 & up.
Double room $3.50 & up; with bath $4.00 & up

" Elysium "

Single room $1.50 & up; with bath $2.50 & up.
Double room $2.50 & up; with bath $3.50 & up.

" Dunsmuir "

Single room $1.00 & up; with bath $2.50 & up.
Double room $1.50 & up; with bath $3.50 & up.

" Lotus "

Single room $1.00 & up; with bath $1.50 & up.
Double room $1.50 & up; with bath $2.00 & up.

" St. Regis "

Single room $1.00 & up; with bath $2.00 & up.
Double room $2.00 & up; with bath $2.50 & up.

All the above hotels are operated on the European plan. All members wishing hotel accommodations engaged for them should communicate immediately with the Local Secretary.

NOTE: Advance copies of the papers may be obtained from the secretary of the Convention Committee, Mr. E. M. Breed, 814 Dominion Trust Building, Vancouver. All except the paper by Mr. K. C. Randall will be found in this issue of the PROCEEDINGS.

Index to the Transactions Ready

The Indexing Transactions Committee announces that Volume 2 of the Index of the TRANSACTIONS, for the decade 1901 to 1910, is ready for distribution, and that Volume I, covering the period from the organization of the Institute to 1900 inclusive, is in press. Volume 2 will be sent gratis to any member of the Institute on written request to the Secretary.

CHARACTER OF THE INDEX

This index of the TRANSACTIONS consists of two separate parts, each intended for a distinct purpose.

1. An index of papers in which they are classified in natural groups and arranged chronologically in each group.
2. An index of specific data and information arranged alphabetically.

The index of papers is intended for searchers desiring to locate papers on a given subject, and to aid in this search the papers have been characterized. These characterizations are not intended to be abstracts of the papers, but rather to give the scope and nature of their contents. The titles of many papers are misleading, and it is hoped thus to call the searcher's attention to the real nature of the contents.

The index of specific data and information is intended for searchers desiring to make a complete study of the subject as presented in the TRANSACTIONS. There is a great mass of valuable information hidden in discussions which has no very direct connection with the subject of the paper. These data can be found only by reference to such a topical index.

A logically arranged classification for this index seemed impossible. Accordingly all information was grouped into natural classes and very complete cross-indexing was provided. The searcher will thus be led to the desired information, whatever may be his ideas of a proper arrangement.

The classification of the papers was determined by sorting them for the

entire period covered by the index. Any group containing a large number of papers was subdivided. All papers were arranged chronologically to enable the searcher to pass over the early papers that might be too old for his use.

Naturally, many papers, especially when considered together with their discussions, fell into a number of different groups. In all such cases they were put into as many places as it was thought they might possibly belong.

The topical index is not a classified index in the ordinary sense. However, all of the information is properly grouped in an alphabetical manner. The conditions it was intended to carry out were: to index all useful specific data and information contained in the TRANSACTIONS, and to arrange the index items in such a manner that anybody could find them with a minimum of trouble.

In the attempt to meet these conditions the following general rules were observed:

1. All subjects are indexed under the noun, and where an adjective is practically inseparably associated with a noun by usage, it has been incorporated with it by a hyphen.

2. All references to a given subject are listed in the same place, so that having found one reference the searcher can rest assured that he has found all.

3. Apparatus and phenomena known by several names are grouped under one name and the other names are inserted in the index with cross references. For instance, inductance coils, reactance coils, reactive coils, choke coils, reactors will be found in the index with cross references to "reactors."

4. Apparatus and phenomena common to two or more subjects are grouped by themselves and cross references are inserted under the related subjects. Thus, commutation is indexed by itself with cross references under generators, d-c.; motors, a-c.; motors, d-c.

5. Apparatus and phenomena of sufficient importance in themselves are indexed alone with cross references under the main heads of which they form a sub-division. Thus, catenary construction is indexed under catenary construction, with cross reference under distribution, railway.

6. All properties of materials and apparatus are indexed under the name of the material or apparatus, except where the references are to the characteristics of the properties themselves. Therefore, a searcher will find under the name of a material all the properties of that material given in the TRANSACTIONS.

7. No distinction is made between singular and plural in arrangement of the items.

An attempt has thus been made to make it possible for a searcher to find all the information which is contained in the TRANSACTIONS. It is believed that this index will greatly increase the value of the TRANSACTIONS.

HISTORICAL NOTES

In 1894 the necessity of indexing the TRANSACTIONS was discussed by the Institute and Professor George E. Shepherd presented a paper on the subject. However, it was 1902 before any serious attempt was made to prepare an index. This early work was under the direction of Mr. W. D. Weaver, then chairman of the library committee.

At first it was planned to have the work done gratis by members of the Institute and the various volumes were assigned to several members, who had volunteered their services. However, this method proved impracticable, and then paid assistants were tried and finally a professional indexer, Mr. J. H. Cuntz, was appealed to and was just about to submit a plan when Mr. Weaver resigned the chairmanship of the Library Committee and thus the Index was given up in 1906 to be taken up at some future date.

In 1910 Mr. Percy H. Thomas revived the Index and suggested a definite plan for the carrying out of the work. Mr. Thomas took up the matter of preparing the Index with Mr. O. A.

Kenyon and then, shortly after work had been begun in perfecting the plan of the Index, the Indexing Transactions Committee, with Mr. George I. Rhodes as chairman, was appointed.

Under Mr. Rhodes's direction, Mr. Thomas's plan was modified and Mr. Kenyon prepared a sample volume which was submitted to the Committee and approved. For three consecutive years, Mr. Rhodes was chosen as chairman of the Committee so that he could complete the work he had begun.

In doing the work the decade **1901** to **1910** was finished first and then the earlier volumes **1884** to **1900** were grouped into one volume.

This Index represents a deal of work and careful thought and it is believed that the membership will welcome it as a key to all the information contained in the TRANSACTIONS.

Only a limited number have been printed so that an idea of the demand could be arrived at before the final run was made. Therefore those who want them should send in their request *at once.*

The *volumes of the Index are free* to members of the Institute of all grades, but will not be sent out except upon written request to the Secretary.

Meeting of Mining Engineers

The American Institute of Mining Engineers will hold a special meeting in the Engineering Societies Building, New York, October 16-17, 1913, under the auspices of the Iron and Steel Committee. This committee extends to those members of the A. I. E. E. who may be interested, a cordial invitation to attend this meeting. The following list of papers has been prepared, all of which will appear in the September and October *Bulletins* of the A. I. M. E.: " Blast Furnace Gas Cleaning," by W. A. Forbes; " The Quality of Cast Iron as Affected by Oxygen, Nitrogen and Other Elements," by J. E. Johnson, Jr.; " Oxygen in Steel," by W. R. Shimer; " New Design of Regenerators for Open Hearth Furnaces," by H. F. Miller, Jr.; " Shock Tests of Cast Steel," by J. H. Hall; "Scoria Process," by E. Stutz; " Briquetting," by Felix A. Vogel; " Uses and Advantages of Briquettes in Blast Furnace Practise," by Felix A. Vogel; " Discussion of the Existing Data as to the Position of Ac_3," by H. M. Howe; " Determination of the Position of Ae_3 in Carbon-Iron Alloys," by H. M. Howe and A. G. Levy; " Ac_1, the Equilibrium Temperature for A_1 in Carbon Steel," by H. M. Howe; " The Divorcing of the Eutecoid in Meteorites," by H. M. Howe; " Thermal and Microscopical Examination of Prof. Howe's Standard Commercial Steels," by G. K. Burgess, J. J. Crowe and H. S. Rawdon; " Influence of Alloying Elements on the Carburization of Steel," by R. R. Abbott; " Some Phases of the Practical Treatment of Tool Steel," by J. V. Emmons; " The Influence of Copper upon the Physical Properties of Steel," by G. H. Clevenger and B. Ray; " Resistance of Steels to Wear in Relation to their Hardness and Tensile Properties," by J. L. Norris; " Paper Comparing the Records of Crucible Furnaces for Steel Making," by J. H. Hall.

The Iron and Steel Committee also invites written discussion of these papers, which may be forwarded to the Secretary of the Institute.

The meeting will close with an informal dinner and smoker on the evening of October 17, to which members of the A. I. E. E. are also cordially invited.

Pittsburgh Convention of Illuminating Engineers September 22-26, 1913

Arrangements are practically completed for the seventh annual convention of the Illuminating Engineering Society, to be held at the Hotel Schenley, Pittsburgh, Pa., September 22-26, 1913. It is confidently expected that the attendance will surpass that of all previous conventions, and for the accommodation of those attending, special trains will be provided, leaving New

York and Chicago on Sunday, September 21.

The local committee has arranged a full program of entertainment features including baseball, golf, tennis, theater and bridge parties, trips to some of Pittsburgh's big industrial plants, automobile rides, and a banquet on Wednesday evening, September 24. The meeting on Tuesday evening will be held in Soldiers Memorial Hall, at which time a description and demonstration of the wonderful lighting effects installed therein will be given.

An attractive souvenir book containing a program of the convention is being prepared, a copy of which will be mailed to each member of the Society, and others desiring it, about a week before the convention.

The following list of paper indicates the comprehensiveness of the program:

"The Cooling Effect of Leading-In Wires upon the Filaments of Lamps of the Street Series Type"—T. H. Amrine.

"The Neon Tube Lamp"—Georges Claude.

"The Pentane Lamp as a Working Standard"—E. C. Crittenden and A. H. Taylor.

"The Use of Nitrogen at Low Pressure in Tungsten Lamps"—G. M. J. MacKay.

"The Photo-Electric Cell in Photometry"—F. K. Richtmyer.

"The Efficiency of the Eye under Different Systems of Illumination—the Effect of Varying the Distribution and Intensity of Light"—C. E. Ferree.

"Some Theoretical Considerations of Light Production"—W. A. Darrah.

"Errors in Photometric Measurements"—by the engineering department of the National Electric Lamp Association.

"The Development of Alternating-Current Luminous Arc Lamps"—C. P. Steinmetz.

"The Quartz Mercury Vapor Lamp and its Application"—W. A. D. Evans.

"Characteristics of Enclosing Glassware"—V. R. Lansingh.

"The Illuminating Engineering Laboratory of the General Electric Company at Schenectady"—S. L. E. Rose.

"Church Lighting"—R. B. Ely.

"Modern Practise in Street Railway Illumination"—S. G. Hibben.

"Hospital Lighting"—W. S. Kilmer.

"Window Lighting"—H. B. Wheeler.

"Distinctive Store Lighting"—C. L. Law and A. L. Powell.

"Some Commercial Aspects of Gas Lighting"—J. E. Philbrick.

"A Problem in Church Lighting"—E. F. Kingsbury.

"New Commercial Fields Opened by Recent Developments in Lamp Manufacture"—by the engineering department of the National Electric Lamp Association.

"The Evolution of Illuminants"—Roscoe E. Scott.

"The Psychological Values of Light, Shade, Form and Color"—F. Park Lewis.

Directors' Meeting, August 8, 1913

The first meeting of the A. I. E. E. Directors for the administrative year beginning August 1 was held in New York on Friday, August 8, 1913, at 2:30 p.m.

There were present: President C. O. Mailloux, New York; Past-President Ralph D. Mershon, New York; Vice-Presidents, A. W. Berresford, Milwaukee, Wis., S. D. Sprong, H. H. Barnes, Jr., and C. E. Scribner, New York; Managers, F. S. Hunting, Fort Wayne, Ind., N. W. Storer, Pittsburgh, Pa., C. A. Adams, Cambridge, Mass., W. B. Jackson, Chicago, Ill., William McClellan, New York. B. A. Behrend, Boston, Mass., Peter Junkersfeld, Chicago, Ill., Lewis T. Robinson, Schenectady, N. Y.; Treasurer George A. Hamilton, Elizabeth, N. J.; and Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting held on June 25 were approved.

President Mailloux announced that in considering the administration of

the Institute's affairs and the appointment of the committees for the coming year, he had reached the conclusion, after consultation with many members of the Board and of the Institute, that the time has come when a change in the management of the Institute's activities will be advantageous and desirable. Mr. Mailloux then described the features of a plan he had worked out for the accomplishment of this object, involving the distribution of the work into departments and the reconstruction of the technical committees.

The Board voted its sanction of the plan by the adoption of the following resolutions:

Resolved, that the President be authorized to divide the various committees and representatives of the Institute into six groups, as indicated below, and that he be authorized to appoint a Vice-President as Councilor of each group, and a Manager as Vice-Councilor.

Membership and Sections Department.

Ways and Means and Public Affairs Department.

Meetings, Functions and Publications Department.

Scientific and International Committees Department.

Technical Committees Department.

Cooperation, Comity and Honors Department.

Resolved, that the President be authorized to appoint a Ways and Means Committee, consisting of the Councilor and Vice-Councilor of each of the six departments into which the various activities of the Institute are grouped, the chairman of this committee to be the Councilor of the Ways and Means and Public Affairs Department, the President and two Junior Past-Presidents to be ex-officio members of this committee, and the Secretary of the Institute to be secretary of this committee.

President Mailloux announced his appointment of the Vice-Presidents and Managers who will act as Councilors and Vice-Councilors in accordance with the above resolution, as follows:

Membership and Sections: H. H. Barnes, Jr., Councilor; J. Franklin Stevens, Vice-Councilor.

Ways and Means and Public Affairs: C. E. Scribner, Councilor; William McClellan, Vice-Councilor.

Meetings, Functions and Publications: S. D. Sprong, Councilor; Lewis T. Robinson, Vice-Councilor.

Scientific and International Committees: J. A. Lighthipe, Councilor; C. A. Adams, Vice-Councilor.

Technical Committees: A. W. Berresford, Councilor; Farley Osgood, Vice-Councilor.

Cooperation, Comity and Honors: W. S. Murray, Councilor; N. W. Storer, Vice-Councilor.

The plan of reconstructing the technical committees was approved in the following resolution:

Resolved that the technical committees of the Institute be reconstituted as follows:

Railway Committee,

Electric Lighting Committee,

Industrial Power Committee,

Telegraphy and Telephony Committee,

Electrochemical Committee,

Electrophysics Committee,

Committee on Use of Electricity in Mines,

Committee on Use of Electricity in Marine Work,

Committee on Electrically Propelled Vehicles,

Committee on Records and Appraisals of Properties.

It shall be the duty of these technical committees to promote and coordinate Institute activity in their respective fields.

In respect of papers and discussions these committees shall report to the Meetings and Papers Committee to correlate the work of these committees in such manner as will effectively provide adequate opportunity for discussion of each of the various topics included within the scope of Institute activity and to arrange the presentation and discussion of such papers as may receive its approval. It shall be the duty also of the Meetings and Papers Committee to provide for the presentation and discussion of all papers relating to subjects within the scope of Institute activity other than those for which initial responsibility is placed upon the committees above named.

In respect of matters affecting standardization or nomenclature the several committees named shall submit to the Standards Committee such recommendations as they may deem proper.

In respect of all matters other than those relating to meetings, papers or standardization, these committees shall report to the Board of Directors of the Institute.

The chairmen of the committees named above and the chairman of the Educational Committee shall be ex-officio members of the Meetings and Papers Committee.

In order that the activities of the various committees may be correlated, the Board passed the following resolution:

Resolved, that the principal technical and scientific committees of the Institute be authorized to form sub-committees and that the chairman of any sub-committee may, with the consent of the chairman of his committee, invite the chairman of any other technical or scientific committee or sub-committee to appoint delegate members to take part in the work of his sub-committee, and the chairman of any sub-committee may also apply for representation through delegates upon other technical or scientific committees.

President Mailloux announced his appointment of the Institute committees and representatives for the present administrative year, as per list printed in this issue.

The Board elected from its own membership the following three members to serve upon the Edison Medal Committee for two years in place of members on the committee whose terms had expired: H. H. Barnes, Jr., William McClellan, and S. D. Sprong. Mr. Ralph D. Mershon was also elected a member ot the committee for the term of one year to fill a vacancy. The Board also confirmed the appointment by the President of Mr. J. Franklin Stevens and H. W. Buck as members of the Edison Medal Committee for the term of five years.

The following Local Honorary Secretaries, whose terms expired on July 31, were reappointed for the two years ending July 31, 1915: Mr. Clare F. Beames, for India: Mr. Richard O. Heinrich, for Germany. Mr. Guido Semenza was appointed Local Honorary Secretary for Italy for the same period.

The action of the Finance Committee in approving monthly bills amounting to $6,266.14, was ratified.

Upon the recommendation of the Board of Examiners the following action was taken on the various applications pending:

Sixty-three applicants for admission to membership in the Institute as Associates were elected, and six students were ordered enrolled.

Elected to the grade of Member: G. A. Johnstone, Anderson, Ind.

Transferred to the grade of Member: Karl E. Czeija, East Pittsburgh, Pa., Blanchard C. Edgar, Columbus, Ohio, William Elmer, Buffalo, N. Y., J. E. Macdonald, Los Angeles, Cal., Royal W. Sorensen, Pasadena, Cal.

Transferred to the grade of Fellow: Harry U. Hart, Hamilton, Ont., Hammond V. Hayes, Boston, Mass.

The special committee appointed by the Board to examine applications for transfer filed under the special section of the Constitution reported a list of two applicants for transfer to the grade of Fellow, and 15 applicants for transfer to the grade of Member, whose applications the committee had examined and found to comply with the requirements of the special section. These 17 applicants were thereupon transferred.

President Mailloux presented a report of the representatives of various societies who attended the organization meeting of the U. S. National Committee of the International Illumination Commission, held in New York on July 18, 1913, at which plans were formulated for the organization of the said commission, which is to be constructed along lines similar to those of the International Electrotechnical Commission. Mr. Mailloux urged the advisability of participation by the Institute in the movement. The Board voted to refer the matter to the Institute's Executive Committee.

The attention of the Board was called to a resolution adopted at a meeting of Section delegates at the Cooperstown Convention in June, suggesting the advisability of providing for local or territorial vice-presidents.

It was voted to refer this resolution to the Sections and Constitutional Revision Committees.

A resolution adopted by the Section delegates requesting the Board of Directors to consider the amendment of Section 51 of the Institute By-Laws relating to the 60-mile limit of Section territory was referred to the Sections Committee for recommendation.

The report of the Committee on Sections Participation in the Conduct of Institute Affairs, which had been dis-

cussed at the meeting of the Section delegates at the Cooperstown Convention, was presented for consideration. Action was deferred and the Secretary was directed to send copies of the report to the members of the Board prior to the next meeting.

A communication was presented from President Mailloux to Dr. Joseph W. Richards, Secretary of the American Electrochemical Society, suggesting cooperation between different technological bodies in the matter of units, standards, nomenclature and notation. The matter was referred to the Standards Committee.

Addresses Wanted

Name	Former address
Adolph L. Fisher,	104 Peabody St., Gardner, Mass.
H. H. Fulton,	915 Empress Ave., Victoria, B. C.
Donald S. Hayes,	Portland, Ore.
Milo T. Keister,	1570 Lincoln St., Denver, Colo.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

Special Section Suit Appealed

The plaintiffs in the Special Section suit against the Institute have appealed from the decision handed down last June by Judge Page of the Supreme Court of the State of New York, which denied them the injunction they had sought. The hearing will be brought on before the Appellate Division of the Supreme Court of the State during the month of October.

Recommended for Transfer, August 5, 1913

The Board of Examiners, at its regular monthly meeting on August 5, 1913, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

TO THE GRADE OF FELLOW

ARMSTRONG, J. R. C., Chief Electrical Engineer, General Vehicle Co., Long Island City, N. Y.

CONDIT, B. C., Chief Engineer, Northwestern Electric Co., Portland, Ore.

DRUM, A. L., Consulting and Construction Engineer, Chicago, Ill.

GOULD, EDWARD F., Assistant to the General Manager and Engineer, Aurora, Elgin & Chicago Railroad Co., Wheaton, Ill.

HARRIS, FORD W., Consulting Engineer, Los Angeles, Cal.

MAVOR, H. A., Electric Engineer, Glasgow, Scotland.

MCLELLAN, WILLIAM, Merz and McLellan, Newcastle-on-Tyne, Eng.

POLLARD, N. L., Electrical Engineer, Public Service Electric Co., Newark, N.J.

TO THE GRADE OF MEMBER

ARTHUR, JAMES B., Instructor in Electrical Engineering, Baltimore Polytechnic Institute, Baltimore, Md.

HUNGATE, JAMES W., Electrical Engi- Spokane & Inland Empire R.R. Co., Spokane, Wash.

WARING, TRACY D., Superintendent, Standard Underground Cable Co., Perth Amboy, N. J.

Transferred to the Grade of Fellow, August 8, 1913

The following were transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on August 8, 1913.

RECOMMENDED FOR TRANSFER BY THE BOARD OF EXAMINERS

HART, HARRY U., Chief Engineer, Canadian Westinghouse Co., Hamilton, Ont.

HAYES, HAMMOND V., Consulting Engineer, Boston, Mass.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

GILL, F., Consulting Engineer, Partner in Gill & Cook, London, England.

WRIGHT, R. I., Electrical Engineer, Electric Controller & Mfg. Co., Cleveland, Ohio.
Total, 4.

Transferred to the Grade of Member, August 8, 1913

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on August 8, 1913.

RECOMMENDED FOR TRANSFER BY THE BOARD OF EXAMINERS

CZEIJA, KARL E., Engineering Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

EDGAR, BLANCHARD C., Assistant General Superintendent, Columbus Railway & Light Co., Columbus, Ohio.

ELMER, WILLIAM, Superintendent Motive Power, B. & A. V. Division, Pennsylvania Railroad, Buffalo, N.Y.

MACDONALD, J. E., Secretary, Joint Pole Committee, Los Angeles, Cal.

SORENSEN, ROYAL W., Professor of Electrical Engineering, Throop Polytechnic Institute, Pasadena, Cal.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

BALLING, GEORGE A., Electrical Supervisor, Isthmian Canal Commission, Gatun, Canal Zone.

CHERRY, L. B., Sales Engineer, Fairbanks-Morse & Co., Hobart, Okla.

CLARY, CLAUDE L., General Manager, Sikeston Ice, Light & Power Co., Sikeston, Mo.

COOPER, J. S. S., Chief Engineer, Samuel & Co., Ltd., Shanghai, China.

DEERY, WALTER J., Commercial Electrical Engineer, General Electric Co., Philadelphia, Pa.

DORSZESKI, VICTOR A., Electrical Engineer and Chief Assistant to W. J. Hagenah, Portland, Ore.

EDWARDS, J. P., Division Traffic Superintendent, Western Union Telegraph Co., Atlanta, Ga.

HEATH, STEPHEN T., Illuminating Engineer, H. W. Johns-Manville Co., Philadelphia, Pa.

JAKOBSEN, B. F., Electrical Engineer, Cerro de Pasco Mining Co., New York, N. Y.

KOESTER, FRANK, Consulting Engineer, New York, N. Y.

MYERS, F. W., Superintendent of Underground Cables, Duquesne Light Co., Pittsburgh, Pa.

RICHHART, WILLIAM S., Electrical Engineer, Westinghouse Electric & Mfg. Co., Philadelphia, Pa.

SHOEMAKER, JOHN F., Manager, Electric Service Co., Cincinnati, Ohio.

SPEAR, JAMES O., JR., Sales Engineer, Fort Wayne Electric Works of General Electric Co., Charlotte, N. C.

WALBRIDGE, JOHN T., Consulting and Contracting Engineer, Chicago, Ill.
Total, 20.

Member Elected August 8, 1913

JOHNSTONE, G. A., Chief Engineer, American Rotary Valve Co., Anderson, Ind.

Associates Elected August 8, 1913

ARNETT, WILLIAM W., JR., Engineering Apprentice, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., Clover Club, Edgewood Park, Pa.

BILLICA, HARRY J., Washington Water Power Co., Spokane, Wash.

BLAISDELL, BENJAMIN H., Chief Engineer, Manila Elec. Railroad & Light Co., Manila, P.I.

BLASSER, BRAXTON, Switchboard Engineer, Westinghouse Electrical & Mfg. Co., Pittsburgh; res., 516 Jeannette St., Wilkinsburgh, Pa.

BOIXEDA, DANIEL P., Electrical Engineer, Ebro Irrigation & Power Co., Ltd., Apartado 491, Barcelona, Spain.

BRODENS, LOUIS N., Electrical Engineer, E. H. Heaps & Co., Vancouver, B. C.

BROWN, GEORGE N., Electrical Engineer, New York State Railways, Gridley Bldg., Syracuse, N. Y.

BURNS, THOMAS, Construction Electrical Engineer, Prince Rupert Hydro-Electric Co., Ltd., Prince Rupert, B. C.

CALDERON, FLORENTINO, 15 William St., New York, N. Y.

CARLTON, HERBERT E., Master Mechanic, Carter Coal Co., Warren, Ky.

COPELAND, THOMAS F., JR., Electrical Engineer, Pacific Gas & Electric Co., San Francisco, Cal.

COUCH, DAVID H., Manager and Chief Engineer, Mayaguez Light & Ice Co., Boulevard Balboa, Mayaguez, P. R.

DEMPSTER, JAMES H. S., Electrical Engineer, Glasgow Corporation Tramways; res., 44 Polwarth Gardens, Hyndland, Glasgow, W., Scotland.

ECKHARDT, CHESTER C., Construction Electrician, General Electric Co., Gatun, C. Z.

EDWARDS, JOSEPH L., Commercial Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 106 Colonial Bldg., Wilkinsburg, Pa.

FERNOW, BERNHARD E., JR., Shop Superintendent, Cutler Hammer Clutch Co., Milwaukee, Wis.

FLETCHER, CHARLES H., City Electrician, City Hall, Vancouver, B. C.

FOWLER, THOMAS R., Superintendent of Construction, Kinloch Telephone Co.; res., 5149 Gates Ave., St. Louis, Mo.

FRIBLEY, W.H., Superintendent of Construction, Raymond, Wash.

GILBERT, JOHN J., Manager Export Dept., Western Electric Co., 463 West St., New York; res., 254 Sterling St., Brooklyn, N. Y.

GILLESPIE, F. MAURY, Superintendent Electrical and Power Dept., Abangarez Gold Fields of Costa Rica, San Jose, Costa Rica.

GINTZ, JACOB, JR., Instructor of Armature Winding, New York Electrical School, 39 West 17th St., New York, N. Y.

HAYNER, DEELDON E., Electrical Draftsman, Electrical Bond & Share Co., 71 Broadway, New York N. Y.

HEHRE, FREDERICK W., Instructor of Electrical Engineering, Columbia University; res., 373 West 116th St., New York, N. Y.

HITCHCOCK, EDWARD, Assistant Electrical Engineer, Public Works Dept., Wellington, N. Z.

HOLLIS, ERNEST P., Publicity Engineer, General Electric Co., Ltd., Wilton, Birmingham, Eng.

HOLLOWAY, WILLIAM R., Electrical Supervisor, Isthmian Canal Commission, Miraflores, C. Z.

IENGAR, G. R. NURSIM, Superintendent, Bangalore Power & Light System, Bangalore, India.

JAHN, FREDERIC L., Agent, New York Edison Co., 55 Duane St., New York, N. Y.

JOHNSON, FRANCIS ELLIS, Instructor in Electrical Engineering, Rice Institute, Houston, Texas.

KENNEDY, CARLTON L., Designing Engineer, Holtzer-Cabot Electrical Co., Boston; res., 30 Franklin St., So. Braintree, Mass.

KESTER, CARL D., Apprentice, Westinghouse Electric & Mfg. Co., Pittsburgh; res., 419 Rebecca Ave., Wilkinsburg, Pa.

KOHN, JULIAN I., Draftsman, Pacific Gas and Electric Co., res., 2088 Broderick St., San Francisco, Cal.

LUTZI, ROY P., Electrical Engineer, Pacific Gas and Electric Co., 445 Sutter St., San Francisco; res., 2306 Virginia St., Berkeley, Cal.

MACEWAN, THOMAS S., Mechanical Engineer, General Electric Co.; res., 9 Washington Square, Lynn, Mass.

MACMURRAY, CHARLES F., Chief Electrician, Colon Electric & Ice Supply Co., Colon, Panama.

MAREAN, GUY B., Superintendent, Guanajuato Power & Electric Co., Guanajuato, Gto., Mex.

MARSHALL, Edward C., Electrical Engineer, General Electric Co., 1311 Oliver Bldg., Pittsburgh, Pa.

MARTIN, RICHARD L., Electrical Engineer, Western States Gas & Electric Co., Richmond; res., 2903 McClure St., Oakland, Cal.

MCCLINTOCK, PAUL, Inspector, Bay State Street Railway Co., 84 State St., Boston; res., 27 Crescent Ave., Chelsea, Mass.

McGuinn, Keith H. R., Engineer of Underground, Western Canada Power Co., Ltd., Vancouver, B. C.
McQuaide, David A., Salesman, Westinghouse Electric & Mfg. Co., 121 East Baltimore St., Baltimore, Md.
Mory, Lewis C., Chief Electrican and Superintendent of Water Works, Lombard, Ill.
Moulden, Eldin S., Chief Assistant Engineer, Municipal Tramways Trust Adelaide, South Australia.
Parkhurst, Austin F., Division Superintendent, Wireless Dept., United Fruit Co., 80 South St., New York, N. Y.
Peart, Lloyd N., General Superintendent, San Joaquin Light & Power Corp'n., Fresno, Cal.
Pierson, Charles A., President, American Electrical Equipment Co., 304 East 10th St., Kansas City, Mo.
Rawden, Leonard F., Municipal Electrician, City Hall, South Vancouver, B. C.
Ridley, Edward N., Telephone Salesman, Northern Electrical & Mfg. Co., res.,1556 William St.,Vancouver, B.C.
Schmid, Vincent H., Assistant to General Foreman, Commonwealth Edison Co., res., 3728 Herndon St., Chicago, Ill.
Schulenburg, William A., Electrical Engineer, Siemens Schuckertwerke S. A. de Electricidad, Apartado 137 Mexico, D. F.
Shaw, Harry C., Division Electrical Engineer, Postal Telegraph Cable Co., Chicago, Ill.
Takahashi, Mitsutaka, Graduate Student, University of Illinois, Urbana; res., 210 E. Green St., Champaign, Ill.
Therkelsen, Eric, Engineering Instructor, University of Washington; res., 4548 20th St., N.E., Seattle, Wash.
Thompson, J. Stockett, Traffic Inspector, Bell Telephone Co., of Pennsylvania, Wilkes Barre, Pa.
Toohey, Frank, Patent Attorney, Western Electric Co., Rue St. Hubert 125, Antwerp, Belgium.
Trimble, Arthur V., Assistant Engineer, In Charge of High Tension Construction, Hydro-Electric Power Commission, Toronto, Ont.
Uweki, Taitaro, Electrical Engineer, Tokyo Electric Light Co.; res 3 Shintomicho, Rokuchome, Kyobashi, Ku, Tokyo, Japan.
Veitch, James, Electrical Engineer, with Charles F. Gray, 1005 Union Trust Bldg.; res., 553 Broadway, Winnipeg, Can.
Wales, William L., Chief Engineer, Yolo County Consolidated Water Co., Woodland, Cal.
Whitney, Frank G., Wire Chief, Pacific Tel. & Tel. Co., 701 East Jefferson St., Los Angeles, Cal.
Wilkinson, Leon C., Foreman of Construction, Garner Print Works and Bleachery, Wappingers Falls, N. Y.
Woollen, Alexander H., Engineer in Electrical Division, Stone & Webster Eng. Corp'n., 147 Milk St. Boston, Mass.
Total 63.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before September 25, 1913.

Aaron, J. A., Wilkinsburg, Pa.
Anderson, J. E., Copper Cliff, Ont.
Anzo, Y., Tokyo, Japan.
Beane, J., Tahontan, Nev.
Birrell, J. D., Wilkinsburg, Pa.
Brown, R. A., Calgary, Alta.
Burroughs, F. S. (Member), Olympia, Wash.
Calhoun, G. K., Annapolis, Md.
Catlin, J. P. (Member), Pittsfield, Mass.
Flint, C. H., Ashland, Me.
Gardner, J. E., Chicago, Ill.
Gee, H. E., Toronto, Ont.

Girvin, C. W., Washington, D. C.
Hershberger, D. C., Turtle Creek, Pa.
McClain, J. R., Edgewood, Pa.
Okabe, E., Toyko, Japan.
Paine, R. A., Jr., Brooklyn, N. Y.
Pigott, R. J. S. (Member), New York, N. Y.
Slaughter, M. S., Ordway, Colo.
Sultzer, M., New York, N. Y.
Tappan, F., Vancouver, B. C.
Taylor, W. J., Lake Buntzen, B. C.
Tea, P. L., New York, N. Y.
Webb, M. E., Stone, Ky.
Williamson, P. B., Montgomery, Ala.
Wurtele, J. S. H., Vancouver, B. C.
Total, 26.

Students Enrolled August 8, 1918

5968 Kivlin, A.P., Rhode Island St.Coll.
5969 Scholz, H. J., Stanford University.
5970 Welker, J. A., Carnegie Tech. Inst.
5971 Worster, L. S., Wentworth Inst.
5972 Krogmann, W.W., Lewis Inst.Tech.
5973 Cutler, H., Wentworth Institute.

Atlanta Technical Societies Affiliate

On July 12, in Atlanta, Ga., there was held, at the City Water Works pumping station, a preliminary meeting to effect a permanent organization of Atlanta technical societies. Representative members of the following organizations were present: American Society of Civil Engineers, American Institute of Architects, American Society of Mechanical Engineers, American Chemical Society, American Institute of Electrical Engineers, and the Engineering Association of the South, all having local Sections. Besides these, individual members of the American Institute of Mining Engineers, the National Electric Light Association, the American Society of Municipal Engineering, the American Water Works Association and the American Public Health Association were in attendance.

After an old-fashioned Georgia barbecue, the meeting was called to order by Mr. Allen M. Schoen, chairman of the Atlanta Section A. I. E. E., who briefly outlined the object of the meeting. He then called upon Mr. James Nisbet Hazlehurst, chairman executive committee of the American Society of Civil Engineers, who spoke on the movement for cooperation, and its advantages, and made an especial plea for the wider participation of the technical man in public affairs.

Mr. Hazlehurst was followed by Mr. L. J. Hill, Jr., president of the Atlanta Section of the Engineering Association of the South, who spoke on the advantages of affiliation of the different technical societies.

Mr. Hal Hentz, representing the American Institute of Architects, spoke strongly on the need of professional advice where technical matters were involved, referring especially to this need in the matter of city parks and buildings.

Mr. J. S. Brogden, of the Georgia Section of the American Chemical Society, and Mr. Park A. Dallis, of the American Society of Mechanical Engineers, were the next speakers.

Upon motion of Professor T. P. Branch, the following representatives of the several separate organizations were continued as executive committeemen: James Nisbet Hazlehurst, L. J. Hill, Jr., Hal Hentz, W. T. Heath, Park A. Dallis and A. M. Schoen. This committee was instructed to formulate a plan for permanent organization and by-laws to govern the organization.

The chairman then called upon the following gentlemen, who expressed themselves as being in entire accord with the movement: Captain R. M. Clayton, chief of construction, City of Atlanta; Mr. A. C. Bruse, architect; Mr. F. H. Granger, member of the Franklin Institute and the American Institute of Mining Engineers; Professor G. N. Mitcham of Auburn Polytechnic and the Alabama State Highway Commission. Brief addresses were also made by Professor H. P. Wood of the Georgia School of Technology, Mr. Paul Norcross and others.

Past Section Meetings

Detroit–Ann Arbor

A meeting of the Detroit–Ann Arbor Section was held on July 12 in Detroit, with a total attendance of 20.

The following officers were unanimously elected: chairman, Professor A. R. Sawyer, of Lansing; vice-chairman, Mr. L. W. Eddy, of Detroit; secretary, Mr. R. K. Holland, of Ann Arbor; vice-secretary, Mr. G. W. Krause, of Detroit.

Professor A. R. Sawyer, who was the delegate of the Section to the Cooperstown Convention of the Institute, presented a report of the convention.

A paper on "Automatic Substation Control" was then presented by Mr. Bishop, of the Edison Illuminating Company of Detroit, after which the Section members and their friends inspected the automatic substation at Rowena and Brush Streets.

Philadelphia

On June 7 the Philadelphia Section held an outing, jointly with the Illuminating Engineering Society, at the Philadelphia Electric Company's athletic field, which was voted a great success. After a baseball game, A. I. E. E. vs. I. E. S., Dr. W. S. Franklin gave a talk on "Baseball Curves," with experimental illustrations. There were about 150 present.

On June 9 the annual election of officers of the Section was held, with the following result: chairman, A. R. Cheyney; managers, R. B. Owens, H. Mouradian, J. D. Israel; secretary-treasurer, H. F. Sanville; assistant secretary, W. F. James.

San Francisco

At a meeting of the newly appointed executive committee of the San Francisco Section on July 16, the following officers were chosen: chairman, A. H. Griswold; vice-chairman, P. T. Hanscom; secretary, A. G. Jones; chairmen of sub-committees: papers, C. J. Wilson; membership, J. P. Jollyman; entertainment, A. G. Jones.

Schenectady

At the recent annual election of the Schenectady Section the following officers were elected: honorary chairman, C. P. Steinmetz; chairman, George H. Hill; vice-chairmen (for two years), H. M. Hobart, C. E. Eveleth, A. H. Kruesi; managers (for two years) John A. Dewhurst, W. L. Merrill, W. L. Upson, H. P. Broderson; secretary, John R. Hewett; treasurer, A. H. Sundheimer. The following vice-chairmen and managers were elected last year for two years and will consequently hold office through this season: vice-chairmen, J. L. Burnham, H. W. Peck, C. M. Davis; managers, G. H. Reid, W. Stewart Clark, J. J. Linebaugh, Chester Lichtenberg.

Personal

Mr. Irwin McNiece, formerly on the erecting engineering staff of the Allis-Chalmers Manufacturing Company, has been transferred to the Salt Lake City office of that company, in the capacity of hydroelectric sales engineer. Mr. McNiece was formerly connected with the old Telluride Power Company (now Utah Power and Light Company) for a number of years. Prior to his transfer, he had been engaged in electric erecting work out of Milwaukee.

Professor Vladimir Karapetoff, professor of electrical engineering at Cornell University, started August 6 on an extended western trip to visit principal hydroelectric developments and high-tension transmission undertakings, stopping at Keokuk, Iowa, Denver, Salt Lake City, Los Angeles, San Francisco, Portland and Seattle. Professor Karapetoff will attend the Pacific Coast Convention of the Institute at Vancouver, B. C., September 9–13, and return to Ithaca about September 20.

Library Accessions

The following accessions have been made to the Library of the Institute, since the last acknowledgment.

American Electrochemical Society. Transactions, Vol. XXIII. South Bethlehem, 1913. (Gift of American Electrochemical Society.)

American Institute of Chemical Engineers. Transactions, Vol. V. New York, 1913. (Gift of Polytechnic Institute of Brooklyn.)

American Institute of Electrical Engineers. Index to TRANSACTIONS, Vol. II, 1901-1910. New York, 1913.

American Mining Congress. Report of the Proceedings of the 15th Annual Session, 1912. Denver, 1913. (Gift of Congress.)

Association of Iron and Steel Electrical Engineers. Proceedings of 6th Annual convention. N.p. 1912. (Exchange.)

Carnegie Library of Pittsburgh. Classified catalogue, 1907-1911. Part III. Natural science and useful arts. Pittsburgh, 1913. (Gift of Carnegie Library of Pittsburgh.)

Chicago Committee on Gas, Oil and Electric Light. Report on investigation of the Commonwealth Edison Company, Chicago, 1913. (Gift of Committee.)

Congreso Cientifico (1° Pan Americano) Derecho Internacional, constitucional e Historia. (Volumen XX.) Santiago de Chile, 1912. (Gift of Congreso Cientifico (1° pan Americano.)

Copper clad steel wire for municipal fire alarm and police signalling systems, report on, to Duplex Metals Company. By F. F. Fowle. N.p. 1911. (Gift of author.)

Electric Wiring and Lighting. By C. E. Knox and G. E. Shaad. Chicago, American School of Correspondence, 1913. (Gift of publishers.)

Gives practical directions for wiring, based on the rules of the National Board of Fire Underwriters. The section on lighting is largely descriptive, and there is a short chapter on photometry. The volume is well illustrated. W.P.C.

Electrical Tables and Memoranda. Ed. 2. By S. P. Thompson. London, 1913. (Purchase.)

Elektrotechnik und Maschinenbau. Zeitschrift des Elektrotechnischen Vereines in Wien. Festnummer 1883-1913. Wien, 1913. (Exchange.)

Iowa Engineering Society. Proceedings of the 25th annual meeting. Iowa City, 1913. (Gift of Society.)

——List of members, corrected to May 1, 1913.

Kansas Engineering Society. Transactions, 1912, 1913. N.p. n.d. (Gift of Kansas Engineering Society.)

Luftfahrt und Wissenschaft. Heft 5. By J. Sticker. Berlin, 1913. (Purchase.)

Die Luftstickstoffindustrie in ihrer volkswirtschaftlichen Bedeutung. By A. Perlick. Leipzig, 1913. (Purchase.)

National Fire Protection Association. Proceedings of 17th annual meeting. Boston, 1913. (Gift of National Fire Protection Association.)

New Subways for New York: The dual system of rapid transit. June, 1913. (Exchange.)

Sensations of Tone. Ed. 4. By H. L. F. Helmholtz. London-New York, 1912. (Purchase.)

Southwestern Electrical and Gas Association. Proceedings of 8th Annual Convention, 1912. N.p. 1912. (Gift of Association.)

Telephone Switchboard Conference, 1887. New York, 1887. (Gift of F. F. Fowle.)

Theory of Sound. Ed. 2. Vols I-II. By Lord Rayleigh. London, 1894, 96. (Purchase.)

Die Verwendbarkeit der Drehstrom-Kommutatormotoren. By C. T. Buff. Berlin, 1913. (Purchase.)

TRADE CATALOGUES

Central Electric Co., Chicago, Ill. Electron, June, 1913.

Chicago Pneumatic Tool Co., Chicago, Ill. Cat. 43—"Rockford" Railway Motor cars.
Bull No. 34 R—Compressors enclosed self-oiling types. May, 1913.

Dossert & Co., New York, N. Y. Solderless connectors. Catalogue. Tenth year. 62 pp.

Edison Storage Battery Co., Orange, N. J. Booklet containing some features of the Chicago convention of the N. E. L. A., 1913. 15 pp.

Electric Controller & Mfg. Co., Cleveland, Ohio. Automatic control of machine tools. By H. F. Stratton. 31 pp.

Esterline Co., Indianapolis, Ind. Graphic meter price list. Jan., 1913.

Fairbanks-Morse & Co., Chicago, Ill. Bull No. 35—Catechism on alternating-current apparatus. June, 1913.

General Electric Co., Schenectady, N. Y. Bull. No. A 4035—Series luminous arc lamps. May, 1913.

——A 4109—Belt-driven revolving armature alternators. May, 1913.

——A 4122—Carrier bus arc panels for brush arc generators. April, 1913.

——A 4123—Automatic voltage regulators. June, 1913.

——A 4125—Parts of type 1-10 Single-phase Thomson induction Watthour meters. 25-133 cycles. May, 1913.

——A 4127—Combined straight and automatic air brake equipment. May, 1913.

——A 4129—Small feeder voltage regulators. May, 1913.

Ohio Brass Co., Mansfield, O. Bulletin. June-July, 1913.

Pettingell-Andrews Co., Boston, Mass. Juice. July-August, 1913.

Sprague Electric Works, New York, N. Y. Bull. No. 246—Motor driven exhaust fan outfits.

Westinghouse, Church, Kerr & Co., New York, N. Y. Work Done (No. 5) Railroad Shop Edition.

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LOUIS DUNCAN, 1895-6-7.	LEWIS B. STILLWELL, 1909-10.
FRANCIS BACON CROCKER, 1897-8.	DUGALD C. JACKSON, 1910-11.
A. E. KENNELLY, 1898-1900.	GANO DUNN, 1911-12.

RALPH D. MERSHON, 1912-13.

*Deceased.

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RALPH W. POPE,
33 West 39th Street, New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York

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As appointed August 8, 1913.

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Revised to September 1, 1913.

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Detroit Ann Arbor.Jan. 13, '11	A. R. Sawyer.	Ray K. Holland, Cornwall Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	T. W. Behan.	P. H. Haselton, Fort Wayne Electric Works. Ft. Wayne, Ind.
Indianapolis-Lafayette Jan. 12, '12	O. S. More.	Charles A. Tripp, 710 Majestic Building, Indianapolis, Ind.
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Pittsburgh.......Oct. 13, '02	E. L. Farrar,	M. C. Turpin, Department of Publicity, W. E. and M. Company, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, General Electric Company, Pittsfield, Mass.
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St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
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Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, British Columbia Electric Railway Company, Vancouver, B. C.
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Armour Institute........Feb. 26, '04	E. L. Nelson,	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	E. M. Richards.	Robert L. Rooke, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost,	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	Clay M. Strait, Univ. of Cincinnati, Cincinnati, Ohio.
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Iowa State College.......Apr. 15, '03	H.C.Bartholomew	F. A. Robbins, Iowa State College, Ames, Iowa.
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Kentucky, State Univ. of.Oct. 14, '10	R. B. Pogue.	W. M. Lane, 216 Rose Street, Lexington, Ky.
Lafayette College........Apr. 5, '12	G. P. Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
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Lewis Institute..........Nov. 8, '07	Ralph Kilner.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Maine, Univ of..........Dec. 26, '06	Howard O.Burgess	J. Larcom Ober, S. A. E. House, Orono, Maine.
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Ohio State Univ.........Dec. 20, '02	L. R. Yeager.	John M. Strait, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Coll...........Oct. 13, '11	A. P. Little,	J. W. Harvey, 416 Hester Street, Stillwater, Okla.
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Oregon Agr. Col.........Mar. 24, '08	Lance Read.	Charles E. Oakes, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	C. R. Reid,	C. H. Van Duyn, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	K. P. Fuhrman.	I. S. Nippes, Pennsylvania State College; State College, Pa.
Purdue Univ............Jan. 26, '03	C. F. Harding.	A. N. Topping, Purdue University, Lafayette, Ind.
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Wash., State Coll of......Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ........Feb. 26, '04	C. E. Wright.	A. S. Blatterman, 45 Lewis Place, St. Louis, Mo.
Worcester Poly. Inst.....Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University..........Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

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PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

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Meeting of A. I. E. E. in New York, October 10, 1913

The 286th meeting of the A. I. E. E. will be held in the auditorium of the Engineering Societies Building, New York, October 10, 1913, at 8:15 p.m.

The general subject of the meeting will be "Tungsten Lamps", and two papers will be presented, as follows: *Tungsten Lamps of High Efficiency* - I, by Irving Langmuir, and *Tungsten Lamps of High Efficiency* - II, by Irving Langmuir and J. A. Orange. The first paper describes investigations into the cause of blackening of the bulbs of tungsten lamps and discusses methods whereby the blackening is avoided and the efficiency of the lamps increased. The second paper describes in detail the new types of high-efficiency tungsten lamps which have been produced by filling the bulbs with nitrogen. These lamps in the larger sizes have an average specific consumption in the neighborhood of one-half watt per candle power, and it is expected that some of these lamps will be shown in operation.

At the close of the technical session the meeting will adjourn to the Institute offices on the 10th floor, where a smoker will be held and refreshments served.

Philadelphia Meeting of the A. I. E. E., October 13, 1913

The 287th meeting of the A. I. E. E. will be held in Philadelphia October 13, 1913, under the auspices of the Philadelphia Section.

The official headquarters of the Institute during the meeting will be the Drexel Institute, 32nd and Chestnut Streets. Afternoon and evening sessions will be held as follows:

AFTERNOON SESSION
1:30 p.m.
at Drexel Institute.

1. *Electric Drive in Machine Shops,* by Charles Fair.
2. *Industrial Substations,* by H. P Liversidge.

Following the afternoon session an inspection will be made of the engineering laboratories and shops of the Drexel Institute.

5:00 p.m.

Visit of inspection will be made to the Electrical Engineering Laboratories of the Towne Scientific School, University of Pennsylvania, at 33rd and Locust Streets.

Dinner 6:30 p.m.

The Normandie, 36th and Chestnut Streets, $1.00 per cover.

EVENING SESSION
8:15 p.m.
at Drexel Institute

3. *Relation of Plant Size to Power Cost,* by Paul M. Lincoln.

The meeting will be in charge of the Local Arrangements Committee, of which Mr. Joseph D. Israel is Chairman, and the Reception Committee, of which Mr. A. R. Cheyney is chairman.

The Electric Club of Philadelphia, has kindly extended the privileges of its club house during the week of October 13th, to members of the A. I. E. E. attending the Philadelphia meeting.

New York Meeting of Mining Engineers, October 16-17, 1913

The American Institute of Mining Engineers will hold a special meeting, under the auspices of the Iron and

Steel Committee, in the Engineering Societies Building, New York, October 16-17, 1913. The Iron and Steel Committee of the A.I.M.E. extends to all members of the A.I.E.E. who may be interested an invitation to attend this meeting.

Some twenty papers on metallurgical subjects have been prepared for presentation at this meeting, and published in the September and October numbers of the *Bulletin* of the A.I.M.E. The list of titles and authors of these papers was given in the September issue of the PROCEEDINGS.

The meeting will close with an informal dinner and smoker on the evening of October 17, to which, also, members of the A.I.E.E. are invited.

President Mailloux Receives Foreign Decoration

President C. O. Mailloux, who is soon expected home from a European trip, where he attended the meetings of the International Illumination Commission in Berlin last August, and the International Electrotechnical Commission in September, has been signally honored by the President of France, who has conferred upon him the decoration of Chevalier of the Legion of Honor. His many friends both at home and abroad are rejoiced to hear of this high distinction and are offering him most hearty congratulations.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 30, 1913.

Ames, M. P., Erie, Pa.
Bourke, R. L., New York, N. Y.
Bowen, O. S., Wollaston, Mass.
Boykin, R. M., Portland, Ore.
Buzzell, R. K., Vancouver, B. C.
Dorting, Emil E., Bloomfield, N. S
Eckbo, O. L., Barcelona, Spain.
Eves, W., 3rd., Wilmington, Del.
Francis, R. W. T., Everett, Mass.
Gilbert, John J., Chicago, Ill.
Hebgen, M. (Member), Butte, Mont.
Henning, C. I. B., Wilmington, Del.
Hockley, W., Vancouver, B. C.
Huson, S. W., Vancouver, B. C.
Kelly, W. F., Vancouver, B. C.
Kenyon, G. F., Vancouver, B. C.
Kirby, L. J., Wilkinsburg, Pa.
Kirkwood, M., New York, N. Y.
Knoeppel, F. W., Buffalo, N. Y.
Knutz, W. H., Chicago Heights, Ill.
Langdon-Davies, W., Vancouver, B. C.
Lauffer, C. A., Wilkinsburg, Pa.
Lewis, W. P., Albuquerque, N. M.,
Lockwood, A. M., San Antonio, Tex.
McGeehan, C. A., Villanova, Pa
McNeill, R. W., Garfield, Utah.
Milligan, F. G., Seattle, Wash.
Milnor, J. W., New York, N.Y.
Morrow, L. W. W., Norman, Okla.
Murphy, W. J., Edmonton, Alta.
Northrup, E. S., Brooklyn, N. Y.
Otis, C. W., Wilkinsburg, Pa.
Pritchard, S.R., (Member), Blacksburg, Va.
Sands, W. H., Jr., Pittsburgh, Pa.
Spiteri, Joseph, Ft. William, Ont.
Thorpe, F. J., Sanborn, N. Y.
Trust, H. G., Rio de Janeiro, Brazil.
Wohra, H. D., Fayetteville, Ark.
Yoshimi, S., Tokyo, Japan.
Total, 39.

Recommended for Transfer, September 16, 1913

The Board of Examiners, at its regular monthly meeting on September 16, 1913, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

TO THE GRADE OF FELLOW

CAMPBELL, GEORGE ASHLEY, Research Engineer, American Tel. & Tel. Co., New York, N. Y.

EDWARDS, J. PAULDING, Consulting Engineer, Sacramento, Cal.

HARPER, J. L., Chief Engineer, Hydraulic Power Co., Chief Engineer, Cliff Electrical Distributing Co., Niagara Falls, N. Y.

MALLET, John P., Electrical Engineer, Diehl Mfg. Co., Elizabeth, N. J.

RUSHMORE, D. B., Engineer, Power & Mining Dept., General Electric Co., Schenectady, N. Y.

SCATTERGOOD, E. F., Chief Electrical Engineer, Bureau of Los Angeles Aqueduct Power, Los Angeles, Cal.

To the Grade of Member

EDWARDS, EVAN J., Associate Engineer, Engineering Dept., National Elec. Lamp Association, Neala Park, Cleveland, Ohio.

GRANT, L. S. F., President and Managing Director, Canadian British Insulated Co., Montreal, Que.

HATHAWAY, J. D., Superintendent, Imperial Wire and Cable Co., Ltd., Montreal, Que.

PUTNAM, W. R., Electrical Engineer and General Manager, Dakota Power Co., Rapid City, S. D.

SINCLAIR, HENRY H., Vice-President, Centinella Improvement Co., Los Angeles, Cal.

SMITH, H. W., Manager Boston Office Ft. Wayne Electrical Works of Ft. Wayne, Indiana, Boston, Mass.

Past Section Meetings

Lynn

The annual business meeting of the Lynn Section was held on August 15, at West Lynn. The following officers and committees were elected: chairman E. R. Berry; secretary, J.A. McManus; executive committee, R. H. Brown, F. S. Hall, W. A. Hall, D. C. Lash, W. H. Pratt; membership committee K. M. Bradley, A. H. Burritt, G. N. Chamberlin, A. L. Ellis, W. G. Fisher, R. H. Ford, W. E. Greenleaf, F. Johnson, B. F. Moody, J. A. Witter, A.K. Warren, E. J. Wilson; entertainment committee, G. H. Alton, J. A. Dalzell, S. C. Rogers.

Mexico

The regular monthly meeting of the Mexico Section was held on August 7 in Mexico City, at the Restaurant Gambrinus. There were 24 members in attendance, and chairman H. S. Foley presided.

The business before the meeting was election of chairman and secretary for the year. Mr. Norman Rowe was elected chairman, and Mr. James Carson was re-elected secretary of the Section.

At the close of the dinner Mr. W. A. Ferguson read a paper on "The Cost of Power by Gas, Oil and Steam, Using Oil Fuel," which was discussed by several of the engineers present.

Addresses Wanted

Name	Former address
Adolph L. Fisher,	104 Peabody St., Gardner, Mass.
H. H. Fulton,	915 Empress Ave., Victoria, B. C.
Donald S. Hayes,	Portland, Ore
Milo T. Keister,	1570 Lincoln St., Denver, Colo.
N. H. Ledford,	Chamber of Commerce, El Paso, Texas.
C. A. LeQuesne, Jr.,	1788 Brooklyn Ave., Brooklyn, N. Y.
J. F. Robbins,	122 S. 5th Ave., Chicago, Ill.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

Personal

MESSRS. D. C. AND WM. B. JACKSON, engineers, announce the removal of their Boston office from 84 State Street to 248 Boylston Street.

MR. HENRY D. JACKSON, consulting engineer, 88 Broad Street, Boston, is on a three months' vacation trip in Bermuda. Mr. Jackson will resume business about January 1, 1914.

MR. A. HENRY PICKLER, engineer in charge of the transformer department of the Crocker-Wheeler Company of Ampere, N. J., since 1904, has severed his connection with that company.

MR. DANIEL S. SMITH, formerly with the Crocker-Wheeler Company, Ampere, N. J., has accepted a position as manager of the repair and service department of the Moline Automobile Company, at East Moline, Ill.

MR. J. S. VIEHE recently resigned from the engineering department of the Electric Bond and Share Company, and is now connected with Westinghouse Church, Kerr and Company of 37 Wall Street, New York, N.Y.

MR. LAWRENCE W. CADY, formerly chief electrical engineer of the Browning Engineering Company of Cleveland, Ohio, and consulting engineer for its allied companies, is now engaged in general consulting engineering work. His mailing address is 1557 Robinwood Avenue, Lakewood, Ohio.

MR. WILLIAM S. ALDRICH, who has been engaged for the past two years on the Shoshone Project of the United States Reclamation Service, at Powell, Wyoming, has been appointed acting professor of electrical and mechanical engineering at the University of Arizona during the sabbatic leave of absence of Professor W. W. Henley.

MR. HENRY FLOY has been appointed by the United States District Court as an appraiser of the property of the John F. Stevens Construction Company, which recently went in the hands of a receiver. This company had a number of large contracts, notably for the construction of two sections of the new subway in New York City, a dam on Salmon River for the Niagara, Lockport and Ontario Power Company and other work.

ING. GUIDO SEMENZA, of Milan, Italy the well known electrical engineer, who was appointed Local Honorary Secretary of the A. I. E. E. for Italy, by President Mailloux, recently received from the King of Italy, the decoration of "Cavvaliere" (knight) of the Crown of Italy.

The many friends of Cavv. Semenza confidently expected this well deserved mark of recognition of his high professional standing and prominence and especially of the admirable work done by him as Secretary of the Turin Electrical Congress. It was quite generally conceded that he was the real organizer of that congress and that its success was due in very great measure to his ability and talents, his genial personality and his tireless activity.

Cavv. Semenza is an old-time member of the A.I.E.E., in which he has many friends and admirers. He was present at the Berlin meetings of the I. E. C. recently, and on this, as on many previous international occasions, showed great loyalty to the A. I. E. E. as well as great courtesy to its representatives. He again assured President Mailloux that he will help in every way to make the San Francisco Electrical Congress a success. From Berlin he has gone to Brazil as the head of an important engineering and expert mission to be absent about two months. He is wearing his A. I. E. E. badge and he will take every opportunity during that trip to "root" for the A. I. E. E. and for the Electrical Congress.

Obituary

CLINTON BERSLEY SMITH, Assoc. A.I.E.E., of Portland, Oregon, assistant engineer of the Pacific Power and Light Company, met his death on July 6, 1913. He and his wife lost their lives in a blizzard while climbing Mount St. Helens. Mr. Smith was graduated from the North Dakota State University in 1900 with the degree of Bachelor of Science. He studied later at the Minnesota State University, receiving the degree of Electrical Engineer from

that institution in 1905. He was elected an Associate of the A.I.E.E. on July 26, 1907. Until 1909 Mr. Smith was connected with the Helena Power Transmission Company of Helena, Montana, and later went to Portland, becoming assistant engineer of the Pacific Power and Light Company. Mr. Smith was a prominent member of the Portland Section of the Institute, and on July 21 his fellow members met to pass resolutions expressing their sorrow at the sad death of Mr. Smith and his wife, and their sympathy with his family in their loss.

ROBERT MURRAY FERRIS, Assoc. A.I.E.E., chief engineer of the New York Telephone Company, lost his life by drowning on July 13, 1913, while in bathing at Siasconset, Nantucket, Massachusetts. Mr. Ferris was born at Chappaqua, N.Y., May 20, 1876. He attended school at Riverview Military Academy, Poughkeepsie, N.Y., and entered the Massachusetts Institute of Technology in 1893, being graduated in 1897 with the degree of Bachelor of Science. He immediately entered the employ of the then New York and New Jersey Telephone Company. Mr. Ferris was elected an Associate of the A.I.E.E. on February 28, 1902. In 1907 he was appointed chief engineer of the New York Telephone Company, and on January 1, 1912, was also appointed chief engineer of several of the subsidiary companies of the American Telegraph and Telephone Company, including the Bell Telephone Company of Pennsylvania and the Chesapeake and Potomac Telephone Company. Mr. Ferris was president of the Telephone Society of New York from 1906 to 1908 and a member of the executive committee of the society for some years prior to his death.

Library Accessions

The following accessions have been made to the Library of the Institute, since the last acknowledgment.

City and Guilds (Engineering) College. Prospectus. Aug., 1913. London, 1913. (Gift of City and Guilds Engineering College.)

The D'Este Steam Engineers' Manual. With an electrical appendix by Charles Penrose. Ed. 2. Boston, 1913. (Gift of Charles Penrose.) Price, $2.00.

The electrical appendix, which occupies three fourths of the book, is intended principally as a practical hand book for the steam engineer who has to do with electrical machinery. W. P. C.

Gli Impianti Idro-Elettrici della Cenischia. Torino, 1913. (Gift of M. Barbieri.)

Incorporated Association of Municipal and County Engineers. Proceedings. Vols. 4, 32. London, 1879, 1906 (Purchase.)

Krupp 1812–1912. Zum 100 Jährigen Bestehen der Firma Krupp und der Guss tahlfabrik zu Essen-Ruhr. Herausgegeben auf den Hundertsten Geburtstag Alfred Krupps N.p.n.d.

This splendidly printed volume giving a history of the great Krupp works at Essen-Ruhr, Germany, is accompanied by a second volume containing an English translation. It is a wonderful contribution to the history of the steel industry. W. P. C.

National Fire Protection Association. Year Book Aug., 1913. Boston, 1913. (Gift of Association.)

——Publications on the subjects of fire prevention and fire protection available in the files and index to subjects covered in the printed records June, 1913. Boston, 1913. (Gift of Association.)

New York State Public Service Commission. Second District. Annual Report. 6th, vols. 1–2. Albany, 1913. (Gift of Commission.)

Osterreichischer Ingenieur und Architektenverein. Jahrbuch, 1913. Wein, 1913. (Gift of Osterreichischer Ingenieur und Architektenverein.)

——Reform des technischen Hochschulwesens in Osterreich. Genehmigt in der Geschäftsversammlung, Apr. 26, 1913. Wien, 1913. (Gift of Osterreichischer Ingenieur und Architektenverein.)

Public Utilities, their cost new and depreciation. By H. V. Hayes. New York, D. Van Nostrand Co., 1913. (Gift of Publishers) Price, $2.00.

This work is written from the standpoint of an engineer, rather than that of an attorney. The present importance of the subject is evidenced by the number of works which have recently appeared. W. P. C.

EXCHANGE ACCOUNT UNIVERSITY OF MICHIGAN

Domestic Engineering (Chicago) Vol. 57 Nos. 5–12; 58 Nos. 1–13; 59, Nos. 1–13. 1911–12.

Iowa Engineering Society. Proceedings of annual meeting 14, 15, 1902–03.

Municipal Journal and Engineer vol. 10, No. 6; vol. 11, Nos. 1, 5, 6, 1901.

Trade Catalogues

Chicago Pneumatic Tool Co., Chicago, Ill. Bull. E-29.—Duntley Electric Grinders. Aug., 1913.

——34-B—"Chicago Pneumatic" Power Driven Compressors. May, 1912.

General Electric Co., Schenectady, N. Y. Bull No. A4121—Direct-current motors, type CVC. June, 1913.

——A4124—Automatic starters for alternating current motors. July, 1913.

——A4130—Adjustable speed direct current motors. July, 1913.

——A4134—Transformer drying and the drying filtering and testing of transformer oil. June, 1913.

——A4135—Lightning arresters for electric railways. June, 1913.

——A4139—Central station oil switches of high rupturing capacity. June, 1913.

Electricity on the New York Central. (Y-283.)

Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Circular No. 1205—Carbon circuit breakers. July, 1913.

United Engineering Society

Association of Iron and Steel Electrical Engineers Convention. Structural steel poles and towers. By R. Fleming. N.p. n.d. (Gift of author.)

Cambria Steel. Handbook of Information relating to Structural Steel Manufactured by the Cambria Steel Company. Johnstown, 1912. (Gift of Cambria Steel Co.)

Chronology of Aviation. By Hudson Maxim and W. J. Hammer. (Reprinted from World Almanac for 1911.) (Gift of W. J. Hammer.)

Columbia University. Catalogue of Officers and Graduates from 1754-1912. New York, 1912. (Gift of Columbia University.)

Efficiency Society. Transactions, Vol. I, 1912. New York, 1913. (Gift of Efficiency Society.)

Fire Tests of Floors in the United States. (International Association for Testing Materials. VIth Congress, New York.) By I. H Woolson. New York, 1912. (Gift of I. H. Woolson.)

International Acetylene Association. Report of Annual Convention. 14th, 15th. Chicago, 1911-12. (Gift of Association.)

Internationalen Kältekongress (Dritten) Festschrift, Washington-Chicago, Sept. 15-24, 1913. Berlin, 1913. (Gift of Internationalen Kaltekongress.)

Moody's Manual of Railroads and Corporation Securities. Volume II, 1913. New York 1913. (Purchase.)

New York Times Index. January-June (2 vols.). New York, 1913. (Purchase.)

Les Nouveaux Livres Scientifiques et Industriels. Vols. 1-2, 1902-12. Paris, 1908, 1913. (Purchase.)

Progress of German Shipbuilding, with special reference to the evolution of the fleet of the Norddeutscher Lloyd. (English-German.) Berlin, 1909. (Gift of North German Lloyd Steamship Co.)

Queens Borough Public Library. Report of the Chief Librarian for the year ending Dec. 31 1912. New York City, 1912. (Gift of Queens Borough Public Library.)

Trow's General Directory of the Boroughs of Manhattan and Bronx, City of New York. Vol. 127, 1913. New York, 1913 (Purchase.)

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RALPH D. MERSHON, 1912-13.

*Deceased.

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As appointed August 8, 1913.

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INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915.

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Revised to October 1, 1913.

Name and when Organized	Chairman	Secretary
Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Baltimore........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, Industrial Building, Baltimore, Md.
Boston...........Feb. 13, '03	N. J. Neall	Leavitt L. Edgar, 39 Boylston St., Boston, Mass.
Chicago.................1893	D. W. Roper.	E. W. Allen, 1028 Monadnock Building, Chicago, Ill.
Cleveland........Sept. 27, '07	J. C. Lincoln.	R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.
Detroit Ann Arbor.Jan. 13, '11	A. R. Sawyer.	Ray K. Holland, Cornwall Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	T. W. Behan.	P. H. Haselton, Fort Wayne Electric Works. Ft. Wayne, Ind.
Indianapolis-Lafayette Jan. 12, '12	O. S. More.	G. B. Schley, 2161 North Meridian St., Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles .....May 19, '08	E. R. Northmore.	C. G. Pyle, 914 Hibernian Bldg., Los Angeles, Cal.
Lynn............Aug. 22, '11	E. R. Berry.	J. A. McManus, Jr., General Electric Co., Lynn, Mass.
Madison.........Jan. 8, '09	Edward Bennett.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	Norman Rowe.	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
Milwaukee.......Feb. 11, '10	L. E. Bogen.	A. J. Goedgen, Milwaukee Electric Ry. and Lt. Co., Milwaukee, Wis.
Minnesota.......Apr. 7, '02	W. T. Ryan.	Fred G. Dustin, 9 South Fifth St., Minneapolis, Minn
Philadelphia......Feb. 18, '03	A. R. Cheyney.	H. F. Sanville, 1326 Chestnut St., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	A. M. Dudley.	E. R. Spencer, 814 Frick Building, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock,	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
San Francisco.....Dec. 23, '04	A. H. Griswold.	A. G. Jones, 819 Rialto Building, San Francisco, Cal
Schenectady......Jan. 26, '03	George H. Hill.	John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.
Seattle.......... Jan. 19, '04	J. D. Ross.	M. T. Crawford, 608 Electric Bldg., Seattle, Wash.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
Toledo..........June 3, '07	George E. Kirk,	Max Neuber, Care of Cohen, Freidlander & Martin, Toledo, O.
Toronto..........Sept. 30, '03	F. A. Gaby.	H. T. Case. Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	A. M. Buck.	
Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, British Columbia Electric Railway Company, Vancouver, B. C.
Washington, D. C Apr. 9, '03	H. C. Eddy.	C. B. Mirick, 1330 New York Avenue, N.W., Washington, D. C.

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Revised to October 1, 1913.

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Arkansas, Univ. of.......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson.	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	E. M. Richards.	Robert L. Rooke, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost.	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	Clay M. Strait, Univ. of Cincinnati, Cincinnati, Ohio.
Clemson Agricultural College..................Nov. 8, '12	J. H. Kangeter.	H. J. Bomar, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	Robert O. Sewell.	R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, '04	L. E. Sweitzer.	Frank A. Redding, University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	E. B. Williams.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.......Apr. 15, '03	H.C.Bartholomew	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of...........May 18, '09	L. F. Hatz.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col....Jan. 10, '08	C. A. Leech.	W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ of.........Mar. 18, '08	S. S. Schooley.	A. J. Fecht, Univ. of Kansas, Lawrence, Kan.
Kentucky, State Univ. of.Oct. 14, '10	R. B. Pogue.	W. M. Lane, 216 Rose Street, Lexington, Ky.
Lafayette College........Apr. 5, '12	G. P Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
Lehigh University.......Oct. 15, '02	W. B. Todd.	G. Forster, Lehigh University, S. Bethlehem, Pa.
Lewis Institute..........Nov. 8, '07	Ralph Kilner.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Maine, Univ of..........Dec. 26, '06	Howard O.Burgess	J. Larcom Ober, S. A. E. House, Orono, Maine.
Michigan Univ of........Mar. 25, '04	Ward F. Davidson	Edward A. Roeser, Univ. of Michigan, Ann Arbor, Mich.
Missouri, Univ of........Jan. 10, '03	H. B. Shaw.	E. W. Kellogg, 9 Engineering Building, Columbia, Mo.
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New Hampshire Col.....Feb. 19, '09	Robin Beach.	Clayton W. Work, New Hampshire College, Durham, N.H.
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	S. B. Sykes.	J. W. Johnson, N. C. College of A. and M. Arts, West Raleigh, N. C.
Ohio Northern Univ.....Feb. 9, '12	George E. Boesger	Harry Restofski, Ohio Northern University, Ada, Ohio
Ohio State Univ.........Dec. 20, '02	L. R. Yeager.	John M. Strait, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Coll...........Oct. 13, '11	A. P. Little,	J. W. Harvey, 416 Hester Street, Stillwater, Okla.
Oklahoma, Univ of.......Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	Lance Read.	Charles E. Oakes, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	C. R. Reid,	C. H. Van Duyn, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	K. P. Fuhrman.	I. S. Nippes, Pennsylvania State College, State College, Pa.
Purdue Univ............Jan. 26, '03	C. F. Harding.	A. N. Topping, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	S. Irwin Stocking.	Joseph E. O'Connell, 457 N. 8th Street, Terre Haute, Ind.
Rhode Island State Coll..Mar. 14, '13	Harry Webb.	L. A. Whittaker.
Stanford Univ...........Dec. 13, '07	G. O. Wilson.	L. M. Bussert, Stanford University, Cal.
Syracuse Univ..........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of ....Feb. 14, '08	J. A. Correll.	Joseph W. Ramsey, University of Texas, Austin, Tex.
Throop College of Technology...............Oct. 14, '10	Ray Gerhart.	R. W. Parkinson, Throop Poly. Institute, Pasadena, Cal.
Univ. of Washington.....Dec. 13, '12	A. P. Newbury.	Charles A. Stanwick, Univ. of Washington, Seattle, Wash.
Vermont, Univ. of.......Nov. 11, '10	Walter L. Upson.	O. Krupp, 65 North Bend St., Burlington, Vt.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	Henry Woodman Clark, A. X. P. House, University, Virginia.
Wash., State Coll of......Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ........Feb. 26, '04	C. E. Wright.	A. S. Blatterman, 45 Lewis Place, St. Louis, Mo.
Worcester Poly. Inst.....Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University..........Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

Total, 47.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

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Vol. XXXII **November, 1913** No. 11

Next A. I. E. E. Meeting, New York, November 14, 1913

The 288th meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineering Societies Building, New York, November 14, 1913, at 8:15 p.m.

The general subject of the meeting will be the electrical equipment of gasoline automobiles, and three papers will be presented, as follows: *Dynamo Electric Lighting for Motor Cars*, by Alfred E. Waller, *Advantages of Clutch Type Generators and of Separate Starting and Lighting Units for Motor Cars*, by Alexander Churchward, and *Electrical Equipment of Gasoline Automobiles*, by Frank Conrad. The members of the Society of Automobile Engineers have been invited to participate at this meeting, and an interesting discussion is anticipated.

At the close of the technical session the meeting will adjourn to the Institute offices on the 10th floor, where a smoker will be held and light refreshments served.

Special Section Suit Ended

The Special Section suit against the Institute was brought to a close on September 29 by the withdrawal on the part of the plaintiffs of the appeal mentioned in the September PROCEEDINGS.

The course followed by the Board of Directors in handling questions arising under the Special Section has therefore now received the sanction and endorsement of the Supreme Court of New York, the Special Section itself providing, in the opinion of the Court, "a convenient, practical and temporary method whereby old members of the society who are eligible for transfer to the grades of Fellow and Member may quickly assume their new title and standing wihout being compelled to go through the routine provided for in the other sections of the constitution."

A detailed reference to the earlier features of the case will be found in the July PROCEEDINGS.

Directors' Meeting, October 10, 1913

The regular monthly meeting of the Board of Directors of the Institute was held in New York on Friday, October 10, 1913, at 3:30 p.m.

There were present: President C. O. Mailloux, New York; Past-President Ralph D. Mershon, New York; Vice-Presidents A.W. Berresford, Milwaukee, Wis., H. H. Barnes, Jr., and Charles E. Scribner, New York; Managers Farley Osgood, Newark, N. J., C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William B. Jackson, Chicago, Ill., William McClellan, New York, L. T. Robinson, Schenectady, N. Y.; Treasurer George A. Hamilton; and Secretary F. L. Hutchinson, New York.

President Mailloux was authorized to change the organization of the Electric Power Committee by substituting for the Sub-Committee on Prime Movers a Committee on Power Generation, and to make the Committee on Prime Movers an independent committee.

President Mailloux announced the following additional committee appointments: Power Generation: H. W. Buck, chairman, Allan V. Garrett, F. G. Gasche, Daniel W. Mead, S. D. Sprong. Committee on Technical Lectures: W. I. Slichter, chairman, W. A. Del Mar, secretary, W. S. Rugg, L. T. Robinson, John B. Whitehead. Committee on Engineering Cooperation: William McClellan, chairman, H. H. Barnes, Jr., A. W. Berresford, Charles E. Scribner, S. D. Sprong.

The action of the Finance Committee in approving monthly bills amounting to $7,235.53 was ratified.

The report of the Finance Committee submitting the annual budget, covering the proposed expenditures for the various activities of the Institute during the appropriation year beginning October 1, 1913, amounting to $111,125.00, was approved, and the budget was adopted.

Upon the petition of the Panama members of the Institute, and the recommendation of the Sections Committee, authority was granted to organize an Institute Section in the Canal Zone, to be known as the Panama Section.

Upon the recommendation of the Board of Examiners the following action was taken on pending applications: Seventy-three applicants were elected Associates. Four students were ordered enrolled.

Messrs. Albert J. Acker, H. Meyer-Delius, and Wilhelm Schenstrom were elected to the grade of Member.

The following applicants were transferred to the grade of Member: James B. Arthur, James W. Hungate, Tracy D. Waring.

The following applicants were transferred to the grade of Fellow: Farley G. Clark, Henry L. Doherty, F. M. Farmer, John B. Fisken, Frederick D. Schick, John A. Walls, Robert M. Wilson, J. R. C. Armstrong, B. C. Condit, A. L. Drum, Edward F. Gould, Ford W. Harris, N. L. Pollard.

The special committee on Transfers reported a list of three applicants for transfer to the grade of Fellow, and eight applicants for transfer to the grade of Member, whose applications the committee had examined and found to comply with the special section of the Constitution, under which they were filed prior to May 1, 1913.

On motion these 11 applicants were transferred to the grades indicated.

In response to an invitation from the National Conservation Congress, the President was authorized to appoint five delegates to represent the Institute at the 5th National Conservation Congress, to be held in Washington, November 18–20, 1913.

Upon the recommendation of the Executive Committee of the Committee on Organization of the International Electrical Congress, President Mailloux was authorized to reorganize the Executive Committee with a chairman and vice-chairman, with the several members of the committee serving also as chairmen of the necessary subcommittees.

The Executive Committee of the Congress also reported that it had unanimously decided to invite Dr. Charles P. Steinmetz to accept the position of Honorary President of the Congress, and Dr. E. B. Rosa to accept the position of Honorary Secretary of the Congress. This action was unanimously approved and confirmed by the Board of Directors.

Addresses Wanted

Name	Former address
N. H. Ledford,	Chamber of Commerce, El Paso, Texas.
J. F. Robbins,	122 S. 5th Ave., Chicago, Ill.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

THE FORUM

Dedicated to the Discussion of Institute Affairs

Suggestions Invited on Institute Publications

It has been evident for several years that some modification in the methods of issuing and distributing the publications of the A. I. E. E. may soon become desirable for the following reasons:

The amount of material published has increased to nearly double what it was a few years ago, and the expense of furnishing all of this material twice to each member (once in the PROCEEDINGS and again in the TRANSACTIONS) is rapidly approaching the limit of the Institute's financial resources. This condition eventually may result either in limiting the activities of the Institute in the amount of matter published, or in adopting some method whereby the duplication of its publication is avoided.

It is also claimed by some members that they are burdened with a large number of papers that are of no special use or interest to them, and they would prefer to receive only papers upon subjects in which they are interested.

The Editing Committee is anxious to find some way to curtail the amount of its publications and still give equally as satisfactory service as at present to the membership. The committee would like to find out what the desires of the membership are in this matter, and to this end it invites suggestions in regard to the Institute publications. One suggestion along these lines, by Mr. Lawrence W. Cady, is printed below, and it is desired that all members who have considered this subject will submit their suggestions for the consideration of the Editing Committee.

If any change in policy is to be made it is hoped that it may be inaugurated January 1, 1914. Therefore prompt response is much desired.

To the membership of the A. I. E. E.:

The excellent address of Past-President Ralph D. Mershon is one that should be carefully considered, and an effort should be made to carry out his ideas.

The writer has a suggestion which he feels will not only help to make the monthly copies of the PROCEEDINGS more valuable to members but also result in lowering the cost of printing and transportation. There is often valuable information contained in the monthly copies which it would be well to have on file for convenient reference, which is not contained in the bound volumes. Under the present system one is obliged either to save these copies, or tear out the information wanted and place it in a file.

The writer suggests that no bound volumes be printed for members to whom monthly copies are sent, but that these monthly copies be mailed in the form of loose leaves, so that they can be inserted in a loose leaf binder. It may be well to have a limited number printed in the present style, but there is a great saving of time and space in using the loose leaf system. Each member could use his own filing system, and everything of special interest would be ready for quick inspection. A great advantage would be that discussions could be filed next to the papers commented on. The present system allows several numbers to separate papers from their discussions, which is a great disadvantage in many ways. It is the writer's opinion that these papers could be printed on the thin so-called India paper, and attractive binders furnished at less cost than the present wasteful method of duplicate printing and transportation. Of course it would take some time and thought in assembling these leaves, but those who would object would have little use for them in whatever shape they arrived. With the present system (which is universal) the articles in the monthly copies overlap so that even if the copies are torn apart, a complex

filing system is necessary where both articles are to be saved. By using more pages this could be avoided in the loose leaf style.

As you are aware, many manufacturers are using this method in keeping their catalogues up to date.

LAWRENCE W. CADY.

Lakewood, Ohio.
August 21, 1913.

CONCERNING PUBLICATIONS OF SISTER SOCIETIES

To the membership of the A.I.E.E.:

I recently had occasion to obtain copies of the *Journal* of the Institution of Electrical Engineers and was surprised to find that the only way to obtain this was through some book concern, or by writing to the Secretary of the British Institute. As a result, I was obliged to pay $1.75 for a single number, the list price being five shillings.

The Electrochemical Society has an arrangement with the Faraday Society, which is the society in England which considers electrochemical matters, whereby an exchange is made and members of each society have Proceedings of the other. While the adoption of this method would, perhaps, not be possible or even advisable for the much larger electrical engineering societies, still I would like to suggest the advisability of an arrangement whereby the members of either society might purchase through the Secretary of their own society the Journal or Proceedings of the other society.

At the present time members of the A.I.E.E. may purchase extra copies of the PROCEEDINGS at a discount of 50 per cent, and I presume that the Institution of Electrical Engineers has a similar arrangement. If this discount were extended by both societies to the members of the other society, it would certainly tend to facilitate greatly the exchange of these periodicals and be of great mutual benefit.

W. J. WOOLDRIDGE.

NOTE: If there is sufficient demand indicated by the membership of the Institute for publications of any of the foreign electrical engineering societies, it may be possible to make a satisfactory exchange agreement with each of the societies concerned, under which, in exchange for a corresponding privilege, the members of the Institute may obtain publications of such societies upon the same terms as the members of the societies issuing the publications are supplied. An agreement on this basis has already been effected between the Institute, the American Society of Mechanical Engineers, and the American Institute of Mining Engineers.

F. L. HUTCHINSON, Secretary.

Pacific Coast A. I. E. E. Convention, Vancouver, B. C., September 9-11, 1912

The fifth annual Pacific Coast Convention of the American Institute of Electrical Engineers was held at Vancouver, B.C., on September 9th, 10th and 11th. Owing to the peculiar business conditions prevailing on the Pacific Coast this year, the attendance was somewhat smaller than originally anticipated, but the convention was a great success, notably from the standpoint of the excellent and complete discussions made possible by considering only one paper at a session. The entertainment features were also particularly well arranged and successful. The total registration was 154, of whom one-third came from places other than Vancouver.

Registration began on Tuesday morning, September 9, at 10 o'clock, and the forenoon was given over to informal receptions and the renewing of old aquaintanceships by the visitors.

The first regular Session was opened on Tuesday afternoon with an address of welcome by a representative of Vancouver's Mayor. Chairman R. F. Hayward then introduced Vice-Presi-

dent J. A. Lighthipe, who presided at all of the sessions, representing President Mailloux. The paper considered at this session was *Snow and Ice Loading on Transmission Lines*, by V. M. Greisser, but owing to the absence of the author, it was read by Mr. C. F. Uhden, chief engineer of the Washington Water Power Company, Spokane, Wash. A thorough discussion followed the reading of this paper, and the meeting then adjourned until Wednesday morning.

On Wednesday morning the paper entitled *Mountain Railway Electrification* was read by its author, Mr. A. H. Babcock of San Francisco. This paper elicited some valuable discussion, as it covered a subject of especial interest to electrical men on the Pacific Coast.

At the afternoon session, which began at 2 p.m., a paper entitled *The Gulf of Georgia Submarine Telephone Cable*, by E. P. La Belle and L. P. Crim, of the British Columbia Telephone Company, of Vancouver, was read. This paper was descriptive of a special type of submarine cable, and its reading was followed by a very general discussion.

The members and guests assembled again at 8:30 p.m., and the first half-hour of the evening was very pleasantly devoted to a piano recital by Professor Vladimir Karapetoff of Cornell University. Then followed an interesting lecture on "Some Features of the Panama-Pacific Exposition," by Mr. A. H. Halloran of San Francisco, which was illustrated with a fine set of stereopticon views. The second part of the piano recital was then given by Professor Karapetoff. At the end of the evening's entertainment, refreshments were served.

On Thursday morning at 10 o'clock the convention reassembled and listened to the reading of a paper entitled *A Modern Substation in the Coeur d' Alene Mining District*, by J. B. Fisken, and also a paper entitled *Notes on Oil Circuit Breakers for Large Powers and High Potentials*, by K. C. Randall. In the absence of Mr. Randall, his paper was read by Mr. A. A. Miller of Seattle. These two papers were very fully discussed and a portion of the discussion carried on into the first part of the afternoon meeting.

At the afternoon session a paper entitled *Logging by Electricity*, by E. J. Barry, was read by Mr. W. E. Herring of Seattle. This paper was received with a great deal of interest and discussed thoroughly. As this completed the list of technical papers, the business sessions of the convention were declared closed, and all of the Institute members and their friends were invited to stay over and take in two trips which had been arranged for Friday and Saturday.

On Thursday evening a banquet was served at the Terminal City Club, which was in every respect a pronounced success. Mr R. F. Hayward, chairman of the convention committee, presided, and introduced the various speakers. Following is the toast list:

"The King."

"The President of the United States."

"The Province of British Columbia."
Proposed by Mr. William Mc Neill.
Responded to by Mr. H. H. Stevens, M.P.; Mayor Baxter.

"American Institute of Electrical Engineers."
Proposed by Mr. R. F. Hayward, Mr. R. H. Sperling.
Responded to by Mr. J. A. Lighthipe, Mr. A. H. Babcock, Mr. F. L. Hutchinson.

"Kindred Societies."
Proposed by Mr. R. W. Pope.
Responded to by Mr. G. R. G. Conway.

"The Technical Press."
Proposed by Professor Karapetoff.
Responded to by Mr. A. H. Halloran, Mr. N. A. Bowers.

The banquet closed with the singing of "God Save the King."

On Friday all of the visitors were the guests of the Western Canada Power Company on a trip to the company's

new power plant at Stave Falls. After a pleasant ride by rail and the inspection of the plant, a luncheon was served. In the afternoon, the party enjoyed a boat ride on Stave Lake. Upon returning to the power plant, tea was served, and the visitors expressed their hearty appreciation of the hospitality extended them by Mr. Hayward, Mr. McNeill, Mr. Nims and the other officials of the Western Canada Power Company.

On Saturday the British Columbia Electric Railway Company were the hosts on a steamer trip to the new Lake Buntzen power plant, situated on the North Arm of Burrard Inlet. This trip gave the visitors an opportunity to appreciate the wonderful mountain scenery of the British Columbia Coast. An orchestra furnished music during the trip. Upon arrival at the power plant, luncheon was served in the high-tension room of the No. 2 Power House, and afterwards the party made a very complete inspection of the new power plant, including a trip to the head works on Lake Buntzen.

After the trip on Lake Buntzen tea was served at the No. 1 Power House, and the party again boarded the steamer for the return trip to Vancouver.

The many expressions of appreciation of the hospitality shown by these two power companies indicated that the entertainment features of the Vancouver Convention were an immense success.

A. I. E. E. Meeting in New York, October 10, 1913

The 286th meeting of the Institute was held in the auditorium of the Engineering Societies Building, New York, on Friday evening, October 10, 1913.

President C. O. Mailloux, in calling the meeting to order at 8:20 p.m., said that the Institute was to be congratulated upon being the means through which another of the great and important steps in the development of electric lighting was to be made public. President Mailloux then introduced Dr. Irving Langmuir, who presented in abstract the two papers of the evening on the subject *Tungsten Lamps of High Efficiency*, as follows: I—*Blackening of Tungsten Lamps and Methods of Preventing It*, by Irving Langmuir, and II—*Nitrogen-Filled Lamps*, by Irving Langmuir and J. A. Orange.

Different forms of the new nitrogen-filled lamps were shown in operation, together with lamps of the older types for comparison. Mr. John B. Taylor began the discussion of the papers, throwing on the screen a projection of the filament used in one of the new lamps, to illustrate his remarks. Those who followed in the discussion were Messrs. John W. Howell, Farley Osgood, J. E. Randall, William McClellan, John W. Lieb, Jr., M. G. Lloyd, H. M. Fales, and Irving Langmuir.

At the conclusion of the technical session, a smoker and social gathering was held in the rooms of the Institute on the 10th floor, where light refreshments were served to the members and guests.

A. I. E. E. Meeting in Philadelphia, October 13, 1913

The 287th meeting of the A. I. E. E. was held in Philadelphia on October 13, under the auspices of the Philadelphia Section. The technical sessions were held at Drexel Institute. Chairman A. R. Cheyney of the Philadelphia Section was the presiding officer. President C. O. Mailloux and Secretary F. L. Hutchinson attended the meeting.

The meeting was called to order at 1:30 p.m. for the first afternoon session. A paper on *Electric Drive in Machine Shops* was presented by Mr. Charles Fair. This was followed by a paper on *Industrial Substations* by Mr. H. P. Liversidge.

The meeting was then taken in charge by Professor A. J. Rowland of Drexel Institute and a committee of professors and students of the Institute, and shown through the engineering laboratories and shops.

This was followed by a visit of inspection to the laboratories and shops of the Towne Scientific School of the Univer-

sity of Pennsylvania, where Professor W. E. S. Temple and a committee of forty students, largely consisting of student members of the Institute, acted as guides.

Eighty-five members met at the Hotel Normandie for dinner at 6:30 p.m., and after the dinner Mr. Mailloux made a short address, in the course of which he dwelt upon the importance of co-operation of all members of the Institute in the International Electrical Congress, to be held in San Francisco, in 1915.

The evening session was called to order at 8:45 p.m., and Mr. Paul M. Lincoln presented a paper on *The Relation of Plant Size to Power Cost.*

Interspersed throughout the meeting was the discussion of the three papers presented, which was participated in by a large number of the members in attendance.

The meeting was adjourned at 11:15 p.m., after a vote of thanks to the Drexel Institute and the University of Pennsylvania for the courtesies extended.

The total attendance at the meeting was 204.

Transferred to the Grade of Fellow October 10, 1913

The following were transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on October 10, 1913.

RECOMMENDED FOR TRANSFER BY THE BOARD OF EXAMINERS

ARMSTRONG, J. R. C., Chief Electrical Engineer, General Vehicle Co., Long Island City, N. Y.

CLARK, FARLEY G., Chief Engineer, Toronto Power Co. Ltd., Toronto, Ont.

CONDIT, B. C., Chief Engineer, Northwestern Electric Co., Portland, Ore.

DOHERTY, HENRY L., President, Cities Service Co., New York, N. Y.

DRUM, A. L., Consulting and Construction Engineer, Chicago, Ill.

FARMER, F. M., Chief Engineer, Electrical Testing Laboratories, New York, N. Y.

FISKEN, JOHN B., Superintendent of Light and Power, Washington Water Power Co., Spokane, Wash.

GOULD, EDWARD F., Assistant to the General Manager and Engineer, Aurora, Elgin & Chicago Railroad Co., Wheaton, Ill.

HARRIS, FORD W., Consulting Engineer, Los Angeles, Cal.

POLLARD, N. L., Electrical Engineer, Public Service Electric Co., Newark, N. J.

SCHICK, D. FREDERICK, Superintendent of Distribution, Philadelphia Electric Co., Philadelphia, Pa.

WALLS, JOHN A., Chief Engineer, Pennsylvania Water & Power Co., Baltimore, Md.

WILSON, ROBERT M., General Superintendent and Chief Engineer, Montreal Light, Heat & Power Co., Montreal, Canada.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

FRASER, J. W., Engineer in Charge, British W. E. &. M. Co., Hobart, Tasmania.

GIBBS, H. P. General Manager and Chief Engineer, Tata Hydro-Electric Co., Bombay, India.

STARK, E. E., City Electrical Engineer, Dunedin City Corporation, Dunedin, New Zealand.

Total, 16.

Transferred to the Grade of Member October 10, 1913

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on October 10, 1913.

RECOMMENDED FOR TRANSFER BY THE BOARD OF EXAMINERS

ARTHUR, JAMES B., Instructor in Electrical Engineering, Baltimore Polytechnic Institute, Baltimore, Md.

HUNGATE, JAMES W., Electrical Engineer, Spokane & Inland Empire R. R. Co., Spokane, Wash.

WARING, TRACY D., Superintendent, Standard Underground Cable Co., Perth Amboy, N.J.

TRANSFERRED IN ACCORDANCE WITH THE SPECIAL SECTION OF THE CONSTITUTION

BROWN, RICHARD P., President, Keystone Electrical Instrument Co., Philadelphia, Pa.

BROWN, SYDNEY W., Superintendent of Erection, Canadian Westinghouse Co., Hamilton, Ontario.

HARDEY, J. ERNEST, Engineer, National Electrical & Engineering Co. Ltd., Dunedin, New Zealand.

JONES, NELSON, National Electrical & Engineering Co., Dunedin, New Zealand.

PERRINE, A., Asst. Prof., Electrical Engineering, Georgia School of Tech., Atlanta, Georgia.

REHFIELD, GROVER G., Electrical Engineer, Chicago Portland Cement Co., Oglesby, Ill.

SHEPHERD, F. R., Chief Electrical Inspector to Council of Fire Underwriters Association of New Zealand, Dunedin, New Zealand.

WINSLOW, FRED ELWOOD, Wire Chief, Chicago Telephone Co., Chicago, Ill.

Total, 11.

Members Elected October 10, 1913

ACKER, ALBERT J., Electrical Engineer, Crocker-Wheeler Co., Ampere; res., 537 No. Grove St., East Orange. N. J.

MEYER-DELIUS, H., Electrical Engineer, General Electric Co.; res., 105 Avon Road, Schenectady, N. Y.

SCHENSTROM, WILHELM, Electrical and Mechanical Engineer, Electric Welding Co., Produce Exchange, New York, N. Y.

Associates Elected October 10, 1913

AARON, JOSEPH A., Engineering Apprentice, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

ABRAHAMS, SAMUEL LIONEL, Electrical Engineer, General Electric Co., Lynn, Mass.

ACKERMAN, PAUL, Electrical Engineer, Toronto Power Co., 12 Adelaide St. E., Toronto, Ont.

ADLER, ERNEST, General Manager, A. E. G. Electric Co., 133 Oxford St., London W., England.

ALLEN, JEREMIAH DEE, Sub-Station Operator, Kansas City Light Co., 604 Wall St., Kansas City, Mo.

ANDERSON, JAMES E., Sub-Station Operator, Canadian Copper Co., Copper Cliff, Ont.

ANZO, YASUKE, Electrical Engineer, Inawashiro Hydro-Electric Power Co., Marunouchi, Tokyo, Japan.

BATES, FRANK J., Los Angeles Aqueduct Power Bureau, Surrey, Cal.

BEANE, JOE, Electrical Superintendent, U. S. Reclamation Service, Tahonton, Nev.

BEARCE, WINFIELD DEXTER, Technical Writer, Ry. & Traction Eng. Dept., General Electric Co., Schenectady; res., Concord St., Scotia, N. Y.

BENNETT, CLARENCE SANSON, Construction Foreman, General Electric Co., Rialto Building, San Francisco, Cal.

BERRY, FREDERICK EDWARD, Electrical Engineer, British Electric Transformer Co., Ltd., Hayes, Middlesex, England.

BIRRELL, JOSEPH DOUGLAS, Graduate Apprentice, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

BOCKOVEN, LEWIS M., Telephone Engineer, Pacific Telephone & Telegraph Co.; res., 128 W. 41st St., Los Angeles, Cal.

BONFIELD, HASWELL THOMAS, Consulting Engineer, Henry Building, c/o Lester W. David Lbr. Co., Seattle, Wash.

BROWN, MELVILLE GILFILLAU, President, Northern Telephone & Power Co. Ltd.; Electrical Contractor, South Fort George, B. C.

BROWN, ROBERT ARTHUR, Chief Electrical Engineer and General Manager, City of Calgary Electric Lighting Dept., City Hall, Calgary, Alberta, Can.

CALHOUN, GUY KNIGHT, Professor of Mathematics, U. S. Naval Academy, Annapolis, Md.

CARDEW, JOHN HAYDON, Electrical Engineer, North Western Railway, Moghalpura, Punjab, India.

CONNERY, FRANCIS COURTNEY, Construction Engineer, Toronto Power Co.; res., 541 Palmerston Blvd., Toronto, Ont.

COOK, JOSEPH, W., Chief Inspector, Vancouver Electrical Department, City Hall, Vancouver, B. C.

DARNBOROUGH, SIDNEY, Construction Foreman, C. C. Moore & Co., Kamloops, B. C.

DEVILVADI-COARACY, V., Professor of Mechanics, 2nd Engineer in Electrical Dept., College of Engg. of Porto Alegre, Rio Grande de Sul Brazil.

DOGHERTY, ALEX. C., Chief Draftsman, Mech. & Elec. Div., T. Pringle & Son, Ltd.; res., 290 St. Joseph Blvd. W., Montreal, Quebec.

FITZPATRICK, WALTER J., Electrical Engineer, State Conservation Commission, Albany; res., 734 Fifth Ave., Watervliet, N. Y.

FLINT, CHARLES HOMER, Construction of Hydro-Electric Plant, Ashland, Maine.

GAILLARD, DAVID ST. PIERRE, Electrical Draftsman, Second Division, Isthmian Canal Commission, Culebra, Canal Zone.

GARDNER, JOHN EDWARD, Electrical Engineer, Chicago, Burlington & Quincy R. R. Co., Room 50, 547 W. Jackson Blvd., Chicago, Ill.

GIRVIN, CHARLES WESLEY, Electrical Inventor & Manufacturer, 507 Victor Building, Washington, D. C.

GOWDA, CHOULGERE RAMABHADRA, Electric Operator Probationer, Cauvery Power Scheme, Government of Mysore, Sivasamudram, India.

HALL, R. DAWSON, Associate Editor, "Coal Age," New York; res. 329 Lincoln Road, Brooklyn, N. Y.

HAY, ALFRED, Professor of Electrical Technology, Indian Institute of Science, Bangalore, S. India.

HERSHBERGER, DAVID CALVIN, Electrical Engineer, General Engineering Div., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 304 Sarah St., Turtle Creek, Pa.

HORD, THOMAS ALAN, JR., Electrical Engineer, John Deere Plow Co.; res., 709 Haines Ave., Dallas, Tex.

HSU, UN D., Student Engineer, General Electric Co.; res., 227 Union St., Schenectady, N. Y.

JOHANSSON, HEMMING JAKOB, Managing Director, Aktiebolaget L. M. Ericsson & Co., Dobelnsgatan 18, Stockholm, Sweden.

KAWASAKI, HIROSHI, Electrical Engineer, Kobe Mitsubishi Dockyard and Engine Works, Kobe, Japan.

KING, LOUIS VESSOT, Assistant Professor of Physics, McGill University, Macdonald Physics Building, McGill University, Montreal Quebec.

KLUGE, HENRY MAURICE, Mechanical Inspector, Testing Department, Crocker-Wheeler Co., Ampere; res., 11 Clearfield Ave., Bloomfield, N. J.

KOBAYAKAWA, TOKIO, Electrical Engineer, Shibaura Engineering Works, Kanasugi, Shiba, Tokyo, Japan.

LYNN, SCOTT, Western New York Representative, Sangamo Electric Co., 109 State St., Rochester, N. Y.

MCCLAIN, JOHN RUSSEL, Inspector Pittsburgh Testing Laboratory, Pittsburgh; res., 131 Edgewood Ave, Edgewood, Pa.

MOMMO, ERNST JAFET, Instrument Tester, Pennsylvania Water & Power Co., Holtwood, Pa.

MOONEY, HARRY V., Electrical Instructor, Heald's Engineering School, 425 McAllister St., San Francisco, Cal.

NEILD, JAMES FREDERICK, Superintendent, Electrical Department, Toronto Railway Co., Toronto, Canada.

OKABE, EIICHI, Electrical Engineer, Inawashiro Hydro-Electric Power Co., Marunouchi, Tokyo, Japan.

ORPIN, CYRIL, Electrical Engineer, Kings Hall Picture Palace Co., Ltd., Dover; res., The "Slopes," Kearsney, Nr. Dover, Kent, England.

OSTROM, WILLIAM A., Canadian General Electric Co., Calgary, Alberta, Can.

OSWALD, WILLIAM S., Draughtsman and Assistant Electrician, City Electrician's Office, City Hall, Vancouver, B. C.

PAINE, ROBERT ALEXANDER, JR., Acting Electrical Engineer, Coney Island & Brooklyn R. R. Co.; res., 148 Montgomery St., Brooklyn, N. Y.

PALMER, PERCY E., Student Apprentice, Fairbanks-Morse Electrical Manufacturing Co., Indianapolis, Ind.

PANNELL, ERNEST VINCENT, Electrical Engineer, British Aluminum Co., 60 W. Front St., Toronto, Ont.

PERKINS, HARRY FRANKLIN, Engineer on High Power Rectifiers, Research Laboratory, General Electric Co., Schenectady, N. Y.

POHE, STEPHEN CLEVELAND, General Superintendent & Treasurer, Columbia & Montour Electric Co., Bloomsburg, Pa.

PORTER, WILLIAM THOMPSON, Electrical Engineer, New Welland Ship Canal; res., 76 Henry St., St. Catherines, Ont.

ROMIG, EUGENE, Assistant Electrical Engineer, United States Electrical Mfg. Co.; res., 812 Laguna St., Los Angeles, Cal.

SETTI, SRIRAM VENKATASUBBA, Power & Lighting Solicitor, Electric Department, Mysore Government, Bangalore City, India.

SLAUGHTER, MADISON SMITH, Local Manager, Ordway Electric Light & Power Co., Ordway, Colo.

SMITH, ALBERT LOYAL, JR., Electrical Contractor, West Medway, Mass.

SULTZER, MORTON, Physical Laboratory Western Electric Co.; res. 15 W. 107th St., New York, N. Y.

SUMMERS, HARRY BENJAMIN, 1336 West 49th St., Los Angeles, Cal.

TAKAKUWA, KAKUICHI, Electrical Engineer, Siemens Schuckert D. K. K., Osaka, Japan.

TAPPAN, FREDERIC, Power Recorder, B. C. Electric Railway Co. Ltd., Vancouver, B. C.

TAYLOR, WILLIAM JOSEPH, Assistant Superintendent, Power House, Vancouver Power Co., Lake Buntzen, B. C.

TEA, PETER LOUIS, Draftsman & Designing Engineer, Pintsch Compressing Co.; res., 75 W. 92nd St., New York, N.Y.

THOMAS, HERBERT PERCIVAL, City Electrical Engineer, City of Nelson; res, 803 Seleca St., Nelson, B. C.

UHLENDORF, EDWARD DORSCH, Appraisal Engineer with W. J. Hagenah. 1stNational Bank Bldg., Chicago, Ill.

VEERHUSEN, HERMAN HELM, Engineering Department, American Telephone & Telegraph Co., 15 Dey St., New York, N. Y.

WATHEN, THOMAS NEAL, Testing Electrical Machinery, Isthmian Canal Commission, Gatun, Canal Zone.

WEBB, MYRTEN ELSWORTH, Chief Electrician and Master Mechanic, Pond Creek Coal Co., Stone, Pike Co., Ky.

WILLIAMSON, PAUL BERNARD, Montgomery, Ala.

WOESTMAN, F. OSKAR, Electrical Engineer, 1841 83rd St., Brooklyn, N.Y.

WURTELE, JOHN STONE HUNTER, Consulting Electrical Engineer, Haffner & Wurtele, 618 Vancouver Block, Vancouver, B. C.

Total 73

Students Enrolled October 10, 1913

5974 Otto, G. E., Dresden Technische Hochschule.

5975 Bartelrue, C. M., Lewis Institute.

5976 Walsh, J. M., Notre Dame Univ.

5977 Wright, J. M., Cornell Univ.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1913.

Arnold, T. H. (Member), Allentown, Pa.
Baker, G. M., Schenectady, N. Y.
Barton, L. C., Jr., Cincinnati, O.
Bird, V. E., New London, Conn.
Blythe, W. E., Syracuse, N. Y.
Bose, S. N., New York, N. Y.
Bottinelli, M. J., Kellogg, Idaho.
Briggs, S. F. Milwaukee, Wis.
Bryan, F. A.(Member),South Bend, Ind.
Cassidy, P. R., Lexington, Ky.
Chakravarti, P. C., Bangalore, India.
Charland, J., Copper Cliff, Ont.
Comins, E. I., Worcester, Mass.
Crippen, C. I., Wheeling, W. Va.
Dainty, W. R., Johannesburg, S. Africa.
Dalal, S. N., Poona, India.
DeBats, C. J., Belleville, Ont.
Duncan, M., New York, N. Y.
Fielding, H. W., Ruskin, B. C.
Follansbee, J. A., Copper Cliff, Ont.
Ford, H. R. (Member), Buffalo, N. Y.
Friden, V. E., Schenectady, N. Y.
Giller, F. S., Hawthorne, Chicago, Ill.
Haddaway, T. S., Webster Groves, Mo.
Hart, A. D., Wilkinsburg, Pa.
Herrlich, H. W., Scotia, N. Y.
Hissink, J. W. (Member), Berlin, Germany.
Hoffman, C. B., Cambridge, Mass.
Holley, R. C., Atlanta, Ga.
Horton, W. H., Jr., Denver, Colo.
Hotson, A. D. (Member), Vancouver, B. C.
Johnson, W. F., Philadelphia, Pa.
Kantorwitz, H., St. Louis, Mo.
Kelley, W. L., Boston, Mass.
Kellogg, W. D., Baltimore, Md.
Kennedy, W. P. (Fellow), New York.
Manypenny, J. P., Philadelphia, Pa.
McClellan, W. D., Richfield, Utah.
McNeal, R. L., Schenectady, N. Y.
Melvin, H. L., Pullman, Wash.
Nichols, H. W., Chicago, Ill.
Oppenheim, B. J., East Orange, N. J.
Perry, E. R., Seattle, Wash.
Peticolas, S. G. (Member), Omaha, Nebr.
Powell, A. L., Newark, N. J.
Ross, D., Jr., London, Ont.
Scholer, A. G., Orange, N. J.
Shirley, E. R., Naughton, Ont.
Simpson, C. W., Chicago, Ill.
Staegemann, E., Suffern, N. Y.
Staples, R. T., New York, N. Y.
Touche, A. S., Chicago, Ill.
Traynor, P. W., Thomas, W. Va.
Watts, E. M., Montreal, Que.
White, L. A., Muskogee, Okla.
Wilder, W. J., Ampere, N. J.

Total, 56.

Past Section Meetings

INDIANAPOLIS-LAFAYETTE

At a meeting of the Indianapolis-Lafayette Section held in Indianapolis on June 20, 1913, officers were elected for 1913-1914 as follows: chairman, O. S. More, Indianapolis; vice-chairman, C. R. Moore, Lafayette; secretary, G. B. Schley, Indianapolis; executive committee, C. F. Harding, Lafayette, Richard Fleming, Indianapolis. Mr. J. L. Wayne was appointed the delegate of the Section to the Cooperstown Convention. At this meeting a paper was presented by Professor C. R. Moore of Purdue University on "Electric Timing Devices." Mr. O. S. More presided at the meeting, and the attendance was 17.

LOS ANGELES

The Los Angeles Section held its first meeting of the season on September 25. The occasion was a dinner and reception to Secretary F. L. Hutchinson and Honorary Secretary Ralph W. Pope. Mr. E. R. Northmore presided, and there were forty-two present. Chairman Northmore announced the committees appointed for the ensuing

year. Several short addresses were made by those present.

Lynn

The first regular meeting of the Lynn Section for the season was held on October 8 at West Lynn. The speaker on this occasion was Mr. H. H. Barnes, Jr., district engineer of the New York office of the General Electric Company, who delivered a lecture on "Rapid Transit in Greater New York." Mr. Barnes emphasized the magnitude of the problems involved by showing that the expenditure of money to provide transportation facilities for the metropolis reached approximately the total cost involved in the construction of the Panama Canal. This large expenditure is necessitated chiefly by the peculiar geographical configuration of New York and the isolation of the outlying districts. Mr. Barnes illustrated his lecture with some fifty lantern slides showing the various types of cars in use from the time of the early horse car to the present steel cars in use in the subway. The manner of driving the under-river tubes by means of hydraulic pistons and the process of joining the sectionalized tubes were also described.

Chairman E. R. Berry presided at this meeting, at which the attendance was 278. The Lynn Section is proud of the fact that there was a larger average attendance at its meetings last year than at the meetings of any other Institute Section.

Mexico

A meeting of the Mexico Section was held on September 11 at the Restaurant Bach in Mexico City. In the absence of Chairman Norman Rowe, who was in London, Mr. James Carson, the secretary, presided. Mr. G. W. Coxon, of the Vera Cruz Electric Light, Power and Traction Company, read a paper entitled "Individual Power Plants versus Electrical City Supply for the Small Consumer." The speaker treated exhaustively the matters of cost, convenience and reliability of service, and stated it as his opinion that individual or isolated plants were successful only in cases of installations not exceeding 200 h.p. where the demand on the generating apparatus was continuous and unvaried. A general discussion followed the presentation of the paper. The total attendance at the meeting was 19.

Pittsburgh

The opening meeting of the Pittsburgh Section was held on September 9 in the Oliver Building. Mr. E. L. Farrar presided and there were 130 members and visitors present. The first business was the election of officers for the year, and those chosen were as follows: chairman, A. M. Dudley; secretary-treasurer, E. R. Spencer, Directors, Messrs. J. W. Welsh, W. C. Oschmann, M. C. Turpin, G. M. Eaton, B. Wiley, and B. C. Dennison. A paper was presented by Mr. S. M. Kintner, engineer and general manager of the National Electric Signalling Company, on the subject of "Radiotelegraphy." Mr. Kintner's talk was illustrated with a large number of photographs projected on the screen, showing different types of apparatus. The newly elected chairman, Mr. A. M. Dudley, made a brief address outlining the plans of the Section for the coming year.

Pittsfield

The Pittsfield Section held its first field day on September 6 at Fontoosuc Lake, and this proved to be a very popular innovation, as the attendance was over 200. A program of field and water events was carried out under the direction of a field day committee composed of Messrs. F. F. Brand, A. Cairns, G. R. Carter, C. Henrichsen, and L. W. Kittridge. A baseball game between teams representing the apprentices and the transformer engineers of the Pittsfield works of the General Electric Company was won by the engineers with a score of 20 to 7. The senior tennis tournament was won by Mr. I. P. Thompson and the junior tourna-

ment by Mr. F. N. Billingslee. The water events included a 50-yard swim, and canoe races and canoe tilting matches.

The Section held a meeting on October 7, at the Maplewood Hotel. Chairman J. J. Frank presided and the total attendance was 180. The speaker of the evening was Dr. C. P. Steinmetz, who took as his subject "The Future of Electrical Development."

San Francisco

The San Francisco Section held a meeting on September 26, in Native Sons Hall. Chairman A. H. Griswold presided, and the total attendance was 207. Mr. W. L. R. Emmet, of Schenectady, addressed the Section on "Electric Propulsion of Large Vessels," paying particular attention to the U.S.S. *Jupiter*, a large collier which has just been completed for the navy. The interesting features of the electric propelling machinery of the *Jupiter* were described with the aid of lantern slides.

Mr. Emmet, who has made a special study of the electric propulsion of large vessels, has been on the Pacific Coast since July, witnessing the tests of the *Jupiter*.

Prior to the meeting, sixteen members of the Institute, including Mr. Emmet, dined together at Marchand's Restaurant.

Seattle

The opening meeting of the Seattle Section was held on September 23, at the Rathskeller Cafe, as an informal dinner, without any technical papers. Thirty-two members and visitors attended. Chairman J. D. Ross reviewed the work of previous years and called for talks by the members as to plans for this year. Short responses were made by Messrs. Harisberger, Howes, Magnusson, Moore, Miller, Terrell, Lindsay, Stanwick, Milligan, Warner, O'Tyson, King and others. Mr. Crawford, who was the delegate of the Section to the Cooperstown Convention, made his report, reading a number of extracts from the proceedings of the Section Delegates.

Toledo

A meeting of the Toledo Section was held on September 12 at the Toledo Commerce Club. The total attendance was 26, and Mr. N. W. Hansen presided. Fourteen new Section members were elected. Suggestions for the work of the coming season were made by many of those present. Mr. Max Neuber then made a brief report of the Cooperstown Convention of the Institute, which he had attended as the delegate from the Toledo Section.

The next meeting of the Section was held on October 3, with an attendance of 30; Chairman George E. Kirk presided. The talk of the evening was given by Mr. Felmeth of the Marion Steam Shovel Company, who spoke on the subject of "Electrically Operated Excavating Machinery," with special reference to gold dredges. Mr. Felmeth showed lantern slides of some gold dredges of 2500 tons displacement, having over 1100 h.p. in electric motors aboard. Some 8-cu. yd. shovels were also shown. An interesting discussion followed, in which many of those present took part.

Past Branch Meetings

University of Arkansas

The first meeting for the 1913-1914 season of the University of Arkansas Branch was held on September 23. Professor W. N. Gladson, dean of the college of engineering, delivered a lecture on "The Engineer of To-day."

University of California

The first meeting of the University of California Branch was held on August 27. Plans for the year were formulated and it was decided to hold regular meetings every second Wednesday evening. Several men were elected to membership in the Branch, and a schedule of papers was arranged.

The next meeting of the Branch was held on September 18, when Mr. Haraden Pratt presented a paper on "Telegraphy," discussing in detail the Sterns, polar and multiplex systems.

At the meeting on September 24 two new members were elected, and two papers were presented. The first paper was "High-Tension Insulator Tests and Considerations for Insulator Design," by Mr. Allen Morrow, and Mr. F. O. Koester presented the second paper, on "Conservation of Water-power."

Another meeting of the Branch was held on October 8, when Mr. W. H. Eller presented a paper on "Load Factors."

University of Colorado

The first meeting, for the season, of the University of Colorado Branch, was held on September 17. Mr. Ernest Burton was elected to fill the vacant office of treasurer. Professor Evans, Professor Jenkins and Mr. Leonard gave short talks on the A.I.E.E. and the opportunities for development afforded by the activities of the local Branch. The new officers outlined the plans for the year.

A meeting of the Branch was held on October 1, when Mr. William Trudgian, of the Westinghouse Electric and Manufacturing Company, read a paper on "The Evolution of the Railway Motor," which had been prepared by Mr. Means of the Denver office of the Westinghouse company. Many interesting slides were shown, which gave a good idea of the characteristic electric railway installations in different parts of the United States.

Highland Park College

A meeting of the Highland Park College Branch was held on July 16, 1913, at which officers were elected for the ensuing year, as follows: president, E. B. Williams; vice-president, S. W. Palmer; secretary-treasurer, R. R. Chatterton; executive committee, H. E. Johnson, J. F. Farner, J. Gailunas.

Mr. C. F. Wright, wire chief of the local district of the Postal Telegraph Company, gave a talk on "The Modern Telegraph," emphasizing the quadruplex system.

The first meeting of the Highland Park College Branch for the 1913-1914 season was held on September 17. Messrs. E. E. Gould and Earl Witzel were appointed as a membership committee, and Messrs. Wilbur Roush, J. F. Farner and Thomas Pellmounter as social committee.

Mr. R. R. Chatterton explained to the new men present the objects of the A. I. E. E. Branch and the advantages of membership. Mr. Wilbur Roush reviewed the Institute paper by Mr. Putnam A. Bates, *Electricity on the Farm*, presented at the Boston Convention in 1912, and then the discussion of this paper by Professor Adolph Shane was taken up for consideration.

Iowa State College

The Iowa State College Branch held a business meeting on September 25, when amendments to the constitution were read. One amendment created the offices of treasurer and recording secretary.

At the next meeting of the Branch, on September 30, these amendments were adopted. The following officers were elected: chairman, E. G. Nichols; treasurer, C. N. Hutchinson; recording secretary, Roscoe Schaeffer; corresponding secretary, Frank A. Robbins; executive committee, C. E. Ide, H. B. Porter, Irving Loveland; social committee, L. G. Swanson, G. C. Hoskins, and E. E. Martin. The treasurer's report was read, and referred to an auditing committee.

University of Kansas

The first meeting of the University of Kansas Branch for the school year

was held on October 8. Professor Johnson gave an interesting illustrated talk on the Panama Canal. The speaker had spent the past summer on work in connection with the canal.

STANFORD UNIVERSITY

The Stanford University Branch held a meeting on October 2 for the purpose of reading over the constitution and by-laws and acquainting the new members with the aims of the society. Committees were appointed to provide for meeting places, speakers, and social events.

WORCESTER POLYTECHNIC INSTITUTE

The first regular meeting of the year was held on October 3, as a joint meeting of the mechanical, civil, and electrical engineering societies of the Institute. The lecture was given by President Ira N. Hollis of Worcester Polytechnic Institute, on "Screw Propellers."

President Hollis's long experience in the U. S. Navy Department, where he became familiar with the design and construction of all types of screw propellers, enabled him to give a very comprehensive lecture on the subject. Illustrated by lantern slides, his subject was covered first historically, then from the standpoint of design and construction.

Mr. D. M. Ormsbee, president of the Mechanical Engineering Society, presided. Attendance was about 175.

Personal

MR. W. D. WEAVER has received from the French Government the decoration (violet rosette) of Officer de l'Instruction Publique.

E. S. LINCOLN, INC., consulting engineers, with electrical testing and research laboratory formerly at Brookline, Mass., have removed to their new laboratories at 129–135 Bacon Street, Waltham, Mass.

MR. VERNE W. SHEAR, recently engineer of the Northern Ohio Traction and Light Company, of Akron, Ohio, is now established as commercial engineer and manufacturer's agent at 609 Flatiron Building, Akron, representing the Condit Electrical Manufacturing Company, Pittsburgh Transformer Company, and other manufacturers. Mr. Shear is a graduate of the Case School of Applied Science, and was for five years commercial engineer with the Westinghouse Electric and Manufacturing Company.

Obituary

FRANCIS VALENTINE TOLDERVY LEE, one of the best-known electrical engineers of the Pacific Coast, died on August 17, 1913, at Victoria, B. C. Mr. Lee was born at Winchester, England, August 28, 1870, the son of Francis V. T. Lee of Shropshire, an officer of the Queen's Own Light Infantry. His early education was received at the Manchester Grammar School, England, and afterwards he attended the College Communal, Boulogne, France. He came to Sherbrooke, Canada, in 1887, and for the greater part of three years was in the service of the Canadian Pacific Railway as private secretary to the division superintendent. He resigned from railroad service to supplement that part of the school training that he had received abroad, with a more adequate technical training in this country. Shortly after his resignation he went to Victoria, B. C., and thence on a trip home to England, after which he returned to New York, where he entered the service of the Manhattan Electric Company in order to gain experience that would enable him to test his liking for electrical engineering. Here he came in contact with the late Dr. F. A. C. Perrine, professor of electrical engineering in Stanford University, California, and there resulted one of the strongest friendships of his life. Often a preceptor exercises a very great influence on the life and personality of a student; particularly is this

true when they come as intimately in contact as did Dr. Perrine and Mr. Lee, who had now entered Stanford University and was working his way through, as secretary and general laboratory assistant to Dr. Perrine.

Shortly after being graduated from the University in 1897, with the degree of B.A. in Electrical Engineering, Mr. Lee was appointed assistant engineer to John Martin, agent for the Pacific Coast department of the Stanley Electric Manufacturing Company. He rose rapidly in this service, being appointed engineer in January, 1898, and manager of the office in June, 1899, and a year later he was made vice-president and general manager of John Martin and Company, electrical engineers and contractors, also Pacific Coast district manager for the Stanley Electric Manufacturing Company, and many other Eastern manufacturers. During this period there came under his direct supervision the erection of many of the earlier lighting and power plants that later were absorbed by the Bay Counties Power Company and the Pacific Electric Railway Company, among others.

On September 27, 1899, he was married to Edith K. Bonnallie of Sherbrooke, Quebec, Canada, who, with his two daughters, Ruth and Margaret, survives him.

Mr. Lee was elected an Associate of the A. I. E. E. on March 23, 1898, and on December 19, 1902, he was transferred to the grade of Member of the Institute.

Early in 1906 he severed his connection with John Martin and Company, but followed Mr. Martin's interests into the Pacific Gas and Electric Company, where he was made assistant to the president. As such he was generally responsible for the construction and operation of the hydroelectric developments of that company.

About three years ago he resigned from the service of the Pacific Gas and Electric Company to enjoy well-earned rest. These last three years were spent in the close companionship of his wife and two daughters, in his old home in England, and travelling on the Continent. They returned a few months ago to Victoria, where he had intended to make his future residence.

At the time of his death he was a member of the American Society of Mechanical Engineers, the Institution of Electrical Engineers, the American Institute of Electrical Engineers, the American Gas Institute, the American Society of Civil Engineers, and the American Electrochemical Society.

Mr. Lee died before much of his work, particularly that of the last seven years, had time to demonstrate its real worth. In all his business life his relations with the really big men with whom he worked brought a mutual confidence and personal regard that in many cases amounted to a real affection. Those who came intimately in contact with him knew his absolute integrity, his uprightness and his unfailing faith in the kindliness of human nature.

LAURENCE J. GALLAGHER, solicitor of patents, Associate of the A. I. E. E., died at his home in New York City on October 5, 1913. Mr. Gallagher was born in Troy, N. Y., on February 12, 1880. He studied electrical engineering in Union College, receiving the degree of B.E. in 1903. He then entered the service of the General Electric Company, in the testing department at Schenectady. In 1905 he became connected with the New York Edison Company, serving in the construction department of that company for two years. On September 28, 1906, he was elected an Associate of the A. I. E. E.

Mr. Gallagher then took up the study of law, and was graduated from the Georgetown Law School in 1909, and was a graduate in patent law from the George Washington University Law School in 1910. From 1909 to 1911 he was an assistant examiner in the United States Patent Office. On November 29, 1911, Mr. Gallagher was married to

Alice J. Carroll, of Albany, who survives him.

From 1911 to the time of his illness, Mr. Gallagher was engaged in teaching applied electricity in the Stuyvesant Evening Trade School, under the New York Board of Education. On February 1, 1913, he opened his law office in New York, at 2 Rector Street, and his thorough knowledge of engineering problems, combined with wide experience in patent law, brought him marked success in the practise of his profession. Mr. Gallagher was a contributor of papers to the Institute. His honesty and ability had gained him many friends in New York City and throughout the state.

Abstracts of Proceedings of Foreign Engineering Societies

Verband Deutscher Elektrotekniker—Annual Meeting at Breslau, 1913

I. Paper by W. Usbeck on "The economic importance of the electric operation of railroads."

A short discursive review is given of the railway field, touching upon all important branches, and the various methods of operation are considered, for electric traction on main lines, with their special advantages contrasted with operation by steam power. These last are of greatest economic importance when current is developed in conjunction with a judicious use of the sources of energy supplied by nature, water power, anthracite and bituminous deposits, and peat fields.

The cheap operating power thus offered may make possible the economical feeding of the mileage of the widely extended system of main lines.

II. Paper by Prof. G. Klingenberg on "The distribution of electrical energy over large areas."

Reference is first made to the methods of calculation applied in practise by the transmission engineer today. Fundamental laws are then developed for the design of the transmission network, illustrated by examples. The equipment of big transformer stations resembles that of the large switching department of the central station. The principal danger encountered incidental to operation consists, as with these, in ignition of oil, which will ever remain difficult to eliminate just so long as recourse must be had to the use of oil switches. Detailed attention is given to a novel suggestion for the removal of this danger, consisting in the substitution of air switches for the oil switches. The equipment of the field stations, the cost of which seriously affects the total cost of installation, is minutely described, particular stress being laid upon the architectural design of such stations. The principles underlying the construction of the system in the field are also considered, and rules are laid down for the transmission, erection and isolation, and the factors of safety to be decided upon. The erection and sinking of poles is then illustrated by means of numerous examples occurring in practise. The question is also taken up in detail, whether foundation poles should be used or not, and in conclusion suitable rules are evolved by means of detailed calculations, for the selection of an economical area of distribution.

III. Paper by Prof. and Dipl. Ing. S. Ruppel, of Frankfort a-M., on "The protection of buildings from lightning."

Many formulas exist for the design of lightning protectors for buildings which involve their erection and maintenance in difficulty. The number of buildings equipped with lightning conductors is in consequence still very small, especially in country districts. Ninety-three per cent of the entire damage due to lightning, however, occurs in the country, and it is there, naturally, that lightning conductors should first be installed.

The greater part of the damage (about 92 per cent) arises through fires, and this could be prevented by the most simple means. Simple lightning conductors may be erected anywhere,

provided the suggestions and recommendations which have been issued by the Electrotechnical Association are followed.

Erection may be greatly simplified and cheapened by means of coöperation, and also the aid of the grounded transmission of local systems.

IV. Paper by Dr. B. Monasch, of Leipzig, on " The modern electrical sources of light."

The field of the arc lamp has been encroached upon for light intensities up to 1000 *HK* by the tungsten incandescent lamp, and for higher light intensities, by high pressure gas. Something has been accomplished with it in the field beyond 1000 *HK* by the use of long-burning flame arc lamps, which, with special electrodes (homogeneous flame carbons), permit a life of 70 to 100 hours for the light obtained with the flame carbons. Schaeffer has developed an alternating-current arc lamp, and Wolffme, a metal vapor lamp with a cadmium amalgam electrode, said to give a white light. Whether these last two sources of light will find practical application in the illuminating field is an open question. The quartz tube mercury lamp has been developed as an individually switched lamp for a 500-volt system.

In the incandescent field the use of the carbon filament lamp has become still more restricted through the increased density secured in the tungsten incandescent body. This mechanical advance was obtained in two ways, entirely distinct, one consisting in the production of the tungsten filaments by the process of drawing, and the other in the use of the old pressure process, but with the innovation that additions are made to the tungsten which permit the pressing of the metal, brittle by itself, into a very flexible and dense incandescent body. Both processes are at the present time in lively competition for supremacy.

Scientific investigations carried on with incandescent lamps have revealed the actual temperature of the incandescent filaments (V. Pirani and Mayer), and also the periodic fluctuations in light intensity occurring during the wave interval of the alternating current (Larsen and Wild). The molecular disintegration of the tungsten incandescent body (scaling), which also takes place with the drawn tungsten material, on a direct current (Brislee), but which is greater with alternating current, in the latter case has not been satisfactorily explained.

Of the sources of light consisting of gases which have been rarefied and enclosed in tubes, the use of the Moore light has been extended for the illumination of interiors and facades. Claude has experimented with tubes containing the permanent gas neon, and has found that these give a light still better than that obtained with the Moore tubes. It could not be learned whether the Claude tubes have yet become a factor to be considered in the technique of practical illumination.

V. Paper by Dr. Weidig and Dipl. Ing. Haensots on " The corona effect in transmission."

A review is given of the corona effects met with in transmission. The laws and properties peculiar to the initial tension are discussed, from cases which have come to light. Corona losses are also considered, together with attempts which have been made at their calculation. Recourse is had to the experiments carried out with a new installation, for the purpose of ascertaining the amount of loss. Dependence is shown upon the wave form and the number of cycles. The volume of loss occurring at the onset of the corona is discussed, together with the visible effects. The losses are ascertained from the familiar formulas used for calculation, and these are compared with the actual results of experimentation. In conclusion, reference is made to the effects which occur at the onset and disappearance of the corona, during change in tension.

Library Accessions

The following accessions have been made to the library of the Institute since the last acknowledgment.

Brooklyn Engineers Club. Proceedings for 1912. Brooklyn, 1913. (Gift of Club.)

Engineers' Club of Philadelphia. Directory, 1913. Philadelphia, 1913. (Gift of Engineers Club of Philadelphia.)

Factory Lighting. By C. E. Clewell. New York, McGraw-Hill Book Co., 1913. (Purchase.)

Fire Appliances—list of manufacturers, published by the National Board of Fire Underwriters. July, 1913. N.p.n.d. (Gift of National Fire Protection Association.)

Franklin Institute. Year Book, 1913. Philadelphia, 1913. (Gift of Franklin Institute.)

Illuminating Engineering Society. List of Members July, 1913. New York, 1913. (Gift of Illuminating Engineering Society.)

International Catalogue of Scientific Literature. 11th Annual issue. C—Physics. London, 1913. (Gift of E. D. Adams Fund.)

International Committee on Electrical Units and Standards of a special technical committee appointed to investigate and report on the concrete standards of the international electricalunits and to recommend a value for the Weston Normal Cell, Report to. January 1, 1912 and supplement. Washington, 1913. (Gift of U. S. Bureau of Standards.)

Massachusetts. Gas and Electric Light Commissioners. Annual Report of the Board. 28th. Boston, 1913. (Gift of Board of Gas and Electric Light Commissioners.)

National Physical Laboratory. Collected Researches. Vol. IX, X, 1913. N.p. (Exchange) Report for the Year 1912. Teddington, 1913. (Exchange.)

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Trade Catalogues

Abenaque Machine Works, Boston, Mass. Portable air compressors. 36 pp.

Central Electric Co., Chicago, Ill. Electron. Aug., 1913

Chicago Pneumatic Tool Company, Chicago, Ill. Bull. No. 148—Hand drills and portable compressors. Sept., 1913.

General Electric Co., Schenectady, N. Y. Bull. No. A4136. Drawn shell type direct current motors with oil ring bearings. July, 1913.

——A4144—Type H form K subway transformers. Aug., 1913.

——A4157—G-E steam, water and air flow meters. Aug., 1913.

——A4137—Curtis steam turbines 100 kw. to 2500 kw. capacity. July, 1913.

Philadelphia Electric Co., Philadelphia, Pa. Bulletin. Sept., 1913.

United Engineering Society

Dinner given to Cass Gilbert, architect. April 24, 1913, by F. W. Woolworth. New York, 1913. (Gift of F. W. Woolworth.)

Duties of the Bureau of Yards and Docks (reprint from Confidential Bulletin No. 13, Public Works of the Navy.) June, 1913. Washington, 1913. (Gift of Alfred Noble.)

Om Hästskosömmetoch dess Tillverkning samt Nagra drag ur Hofbeslagets Historia. By K. J. Sunström. Orebro, 1911. (Gift of F. B. Gilbreth.)

The author desires very much to have samples of every kind of horseshoe nail that there is, in order that his next book on this subject may include America as well as European. K. J. Sunström, Orebro, Sweden.

National Paving Brick Manufacturers' Association. Forms for special assessments, Illinois. N.p. 1913.

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——A compilation of the laws of Ohio affecting the Regulation of Railroads and Public Utilities. 1913. Columbus, 1913.

——An act to create the public utilities commission of Ohio to prescribe its organization etc. N.p. 1913. (Gift of Ohio Public Service Commission.)

Society for the Promotion of Engineering Education. Proceedings of the twentieth annual meeting. Vol. XX, part 2. Ithaca, N. Y., H. H. Norris, 1913. Price $1.25. (Gift of Society for the Promotion of Engineering Education.)

An especially interesting series of papers on engineering laboratories. Professor Magruder

of Ohio State University made a visit to about twenty-five American mechanical laboratories, and summarizes his discoveries. W. P. C.

Thirty Years of New York, 1882–1912, being a history of electrical development in Manhattan and the Bronx. New York, Press of The New York Edison Company, 1913. (Gift of New York Edison Company.)

This is an extremely interesting volume, giving not only a history of the company, showing its marvelous growth, but containing much matter relating to old-time New York, the New York of the horse car, the gas light, and the elevatorless building; a city without electric cars or telephone. The work is profusely illustrated, having many reproductions of sketches by Joseph Pennell, Vernon Howe Bailey and others.

A comparatively small edition was printed. This is regrettable, for the book deserves a wide circulation. This is one of two books in the Library which the Librarian has read through.

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LIST OF SECTIONS.

Revised to November 1, 1913.

Name and when Organized	Chairman	Secretary
Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Baltimore........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, Industrial Building, Baltimore, Md.
Boston...........Feb. 13, '03	N. J. Neall	Leavitt L. Edgar, 39 Boylston St., Boston, Mass.
Chicago.................1893	D. W. Roper.	E. W. Allen, 1028 Monadnock Building, Chicago, Ill.
Cleveland........Sept. 27, '07	J. C. Lincoln.	R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.
Detroit Ann Arbor.Jan. 13, '11	A. R. Sawyer.	Ray K. Holland, Cornwall Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	T. W. Behan.	P. H. Haselton, Fort Wayne Electric Works. Ft. Wayne, Ind.
Indianapolis-Lafayette Jan. 12, '12	O. S. More.	G. B. Schley, 805 Pythian Building, Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles......May 19, '08	E. R. Northmore.	C. G. Pyle, 914 Hibernian Bldg., Los Angeles, Cal.
Lynn............Aug. 22, '11	E. R. Berry.	J. A. McManus. Jr., General Electric Co., Lynn, Mass.
Madison.........Jan. 8, '09	Edward Bennett.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	Norman Rowe.	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
Milwaukee.......Feb. 11, '10	L. E. Bogen.	A. J. Goedgen, Milwaukee Electric Ry. and Lt. Co., Milwaukee, Wis.
Minnesota ......Apr. 7, '02	W. T. Ryan.	Fred G. Dustin, 9 South Fifth St., Minneapolis, Minn.
Panama..........Oct. 10, '13		
Philadelphia......Feb. 18, '03	A. R. Cheyney.	H. F. Sanville, 1326 Chestnut St., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	A. M. Dudley.	E. R. Spencer, 814 Frick Building, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock,	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
San Francisco.....Dec. 23, '04	A. H. Griswold.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady......Jan. 26, '03	George H. Hill.	John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.
Seattle...........Jan. 19, '04	J. D. Ross.	M. T. Crawford, 608 Electric Bldg., Seattle, Wash.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
Toledo ....June 3, '07	George E. Kirk,	Max Neuber, Care of Cohen, Freidlander & Martin, Toledo, O.
Toronto..........Sept. 30, '03	F. A. Gaby.	H. T. Case. Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	Morgan Brooks.	I. W. Fisk, University of Illinois, Urbana, Ill.
Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, 1003 Holden Building, Vancouver, B. C.
Washington, D. C. Apr. 9, '03	H. C. Eddy.	C. B. Mirick, 1320 N Street, N.W., Washington, D. C.

Total, 30.

LIST OF BRANCHES.

Revised to November 1, 1913.

Name and when Organized	Chairman	Secretary
Agricultural and Mechanical College of Texas.......Nov. 12, '09	D. B. Pickens.	E. C. Rack, A. & M. College, College Station, Tex.
Arkansas, Univ. of.......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute.........Feb. 26, '04	E. L. Nelson,	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	F. O. Schnure.	J. M. Hillman, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	Clay M. Strait, Univ. of Cincinnati, Cincinnati, Ohio.
Clemson Agricultural College..................Nov. 8, '12	J. H. Kangeter.	H. J Bomar, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	Robert O. Sewell.	R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, '04	L. E. Sweitzer.	Frank A. Redding, University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	E. B. Williams.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.......Apr. 15, '03	Earle G. Nicnols.	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of...........May 18, '09	L. F. Hatz.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col....Jan. 10, '08	C. A. Leech.	W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ of.........Mar. 18, '08	S. S. Schooley.	A. J. Fecht, Univ. of Kansas, Lawrence, Kan.
Kentucky, State Univ. of.Oct. 14, '10	H. B. Hedges.	H. Tyler Watts, 315 East Maxwell Street Lexington, Ky
Lafayette College........Apr. 5, '12	G. P. Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
Lehigh University.......Oct. 15, '02	W. B. Todd.	G. Forster, Lehigh University, S. Bethlehem, Pa.
Lewis Institute..........Nov. 8, '07	Ralph Kilner.	A. H. Fensholt, Lewis Institute, Chicago, Ill.
Maine, Univ of..........Dec. 26, '06	Howard O.Burgess	J. Larcom Ober, S. A. E. House, Orono, Maine.
Michigan Univ of........Mar. 25, '04	P. H. Evans.	W. B. Kopfer, 616 Church Street, Ann Arbor, Mich.
Missouri, Univ of........Jan. 10, '03	H. B. Shaw.	E. W. Kellogg, 9 Engineering Building, Columbia, Mo.
Montana State Col.......May 21, '07	Lawrence Wylie.	J. A. Thaler, Montana State College, Bozeman, Mont

LIST OF BRANCHES—Continued.

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Nebraska, Univ of.......Apr. 10, '08	Olin J. Ferguson.	V. L. Hollister, Station A, Lincoln, Nebraska
New Hampshire Col.....Feb. 19, '09	Robin Beach.	Clayton W. Work, New Hampshire College, Durham, N.H.
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	S. B. Sykes.	J. W. Johnson, N. C. College of A. and M. Arts, West Raleigh, N. C.
Ohio Northern Univ.....Feb. 9, '12	George E. Boesger	Harry Restofski, Ohio Northern University, Ada, Ohio.
Ohio State Univ.........Dec. 20, '02	L. R. Yeager.	John M. Strait, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Coll...........Oct. 13, '11	A. P. Little,	J. W. Harvey, 416 Hester Street, Stillwater, Okla.
Oklahoma, Univ of.......Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	Lance Read.	Charles E. Oakes, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	C. R. Reid,	C. H. Van Duyn, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	T. A. Jones.	A. D. Shultz, State College, Pa.
Purdue Univ. ....Jan. 26, '03	C. F. Harding.	A. N. Topping, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	E. D. N. Schulte.	W. J. Williams, Rensselaer Poly. Institute, Troy, N. Y
Rose Polytechnic Inst....Nov. 10, '11	Charles F. Harris.	Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.
Rhode Island State Coll..Mar. 14, '13	Harry Webb.	P. M. Randall, Rhode Island State College, Kingston, R. I.
Stanford Univ...........Dec. 13, '07	G. O. Wilson.	L. M. Bussert, Stanford University, Cal.
Syracuse Univ..........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.........Feb. 14, '08	J. A. Correll.	Joseph W. Ramsey, University of Texas, Austin, Tex.
Throop College of Technology................Oct. 14, '10	Ray Gerhart.	R. W. Parkinson, Throop Poly. Institute, Pasadena, Cal.
Univ. of Washington.....Dec. 13, '12	A. P. Newbury.	Charles A. Stanwick, Univ. of Washington, Seattle, Wash.
Vermont, Univ. of.......Nov. 11, '10	Walter L. Upson.	O. Krupp, 65 North Bend St., Burlington, Vt.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	Henry Woodman Clark, A. X. P. House, University, Virginia.
Wash., State Coll of......Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ........Feb. 26, '04	C. E. Wright.	A. S. Blatterman, 45 Lewis Place, St. Louis, Mo.
Worcester Poly. Inst.....Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University.........Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

Total, 47.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

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Vol. XXXII **December, 1913** No. 12

Next A. I. E. E. Meeting, December 12, 1913

The 289th meeting of the A. I. E. E. will be held in the auditorium of the Engineering Societies Building, New York, December 12, 1913, at 8:15 p.m.

The general subject of the meeting will be "*insulating materials*", and the meeting will be opened by the presentation of a paper on *The Dielectric Strength of Thin Insulating Materials*, by Mr. F. M. Farmer of the Electrical Testing Laboratories, New York. Further communications on this subject will be presented by Messrs. E. E. F. Creighton and F. W. Peek, Jr., of the General Electric Company, and by Messrs. C. E. Skinner, R. P. Jackson, and Phillips Thomas of the Westinghouse Electric and Manufacturing Company. As this subject enters into every branch of electrical engineering, a full and interesting discussion is assured.

At the close of the technical session the meeting will adjourn to the Institute offices on the 10th floor, where a smoker will be held and light refreshments served.

Index of Transactions, 1884-1900, Ready

Volume 1 of the Index of the TRANSACTIONS of the American Institute of Electrical Engineers, covering the years 1884-1900 inclusive, has been completed by the Indexing Transactions Committee and is now ready for distribution. Volume 2 of the Index, covering the decade 1901-1910, has already been issued. A copy of Volume 1 has been sent to each member to whom Volume 2 had previously been mailed. Both volumes of the Index will be sent gratis to any other member of the Institute who makes application to the Secretary.

An article in the September PROCEEDINGS described the plan of the Index, and briefly recounted the successive steps in the development of the plan since the project was first discussed in 1894.

The Index of the TRANSACTIONS consists of two separate parts, each intended for a distinct purpose:

First, an index of papers, in which they are classified in natural groups and arranged chronologically in each group. The title and author are given in each case, with a brief statement of the contents of the paper, names of those who took part in the discussion of the paper, and mention of the main topics of the discussion. Reference is given to volume number, year, and page.

Second, a topical index of specific data and information, arranged alphabetically. This part of the index furnishes a guide to all the information contained in the TRANSACTIONS, much of which has hitherto been difficult to locate because it had no very direct connection with the subject of the paper or discussion. All the information is grouped naturally under nouns and phrases, followed by modifying adjectives and sub-classes, all arranged alphabetically. Frequent cross-references are given, and volume number, year, and page, to locate the items in the TRANSACTIONS.

As stated above, the two volumes of

the Index cover the period from the organization of the Institute (1884) to 1910 inclusive. An index arranged on a similar plan, covering the matter contained in the papers and discussions during the year, is now published in each annual volume of the TRANSACTIONS, beginning with 1911.

The Library of the United Engineering Society

The following description of this library is written with the hope of influencing the members of the Institute to make greater use of it. Of those persons who now avail themselves of its privileges, a very small number is to be found in the membership list of this society. It is hoped and believed that this is due to ignorance of the great value and unique character of the contents of its shelves and of their availability. If such be the case, the remedy is publicity.

It comprises the separate libraries of the American Institute of Electrical Engineers, of the American Society of Mechanical Engineers, and of the American Institute of Mining Engineers, as well as its own collections. Its 50,000 volumes are closely related to the field of engineering. They include very little that is non-technical, but comprise the general reference books of the allied sciences such as physics, chemistry, and mathematics, and all the worthy engineering text-books. The Latimer Clark Collection, which was presented to the Institute by Dr. Schuyler Skaats Wheeler, contains every publication in the English language on the subject of electricity appearing prior to 1886. The great strength of the library, however, flows from its enormous collection of current and bound sets of engineering periodicals. Any one from over seven hundred different current journals or proceedings of societies is instantly available to a user of this library. These are not limited to the English language, but the French, German, Italian, Russian, Japanese, Swedish, Norwegian, Danish, Dutch, Polish, Hungarian, Bohemian, and Greek languages are represented. Among these there are over 50 periodicals published in the Spanish language—many from South America. Translations from any of these foreign languages can be obtained at short notice from the library's translators. Many of these periodicals are not to be found in any other library in the United States, and over fifty of them are not in the lists of even the Library of Congress. The collections in the library make it the best engineering library in the United States and probably the best in the world.

The library occupies all of the thirteenth floor and a portion of the twelfth floor of the Engineering Societies Building at 33 West 39th Street, New York City. A mezzanine gallery, accomodating 15,000 volumes, has been installed recently above the former floor. Two ornamental steel cases, designed by Mr. Henry G. Morse, for housing and exhibiting a portion of the Latimer Clark collection, have been located at either side of the main entrance to the library. Available to the public, upon entering the library, are complete author and subject card catalogues of the collection. The wonderfully complete author catalogue, which was published in two bound volumes by the Institute, was edited by Mr. W. D. Weaver, with an introduction and critical notes by Brother Potamian (M. F. O'Reilly,) Professor of Physics, Manhattan College. A very carefully prepared list of the serial and society publications in the library has been published, and is available upon application. The copy for a union list of the technical periodicals in seven of the libraries of the city has been prepared and its appearance from the press may be expected in the near future.

With a view to placing the facilities of the library at the disposal of the out-of-town members of the Founder

Societies and others, a research department was established about three years ago. Upon application to the library, bibliographies are prepared for these members on any desired engineering subject. If, after its receipt by the member, unavailable references prove to have been listed, upon further application copies, abstracts, translations or photographs are supplied. At present a small fee is charged for this work, although a list not requiring more than one-half hour in its preparation is sent gratis. Since the inauguration of this service over five hundred bibliographies have been prepared for persons variously located, even in such places as Patagonia, Australia, Ceylon, and Johannesburg. Not as much as five per cent of these have been upon electrical engineering subjects!

The administration of the library is in the hands of its Librarian, Dr. W. P. Cutter, and assistants, under the direction of a Library Board consisting of five members from each Founder Society. It is the desire of all concerned with its management that its usefulness should be extended as much as possible. Suggestions and criticisms are welcomed. Any engineering book not to be found in its collection will, within reason, be purchased upon request, oral or written.

SAMUEL SHELDON,
Chairman, Library Committee.

The Electric Power Committee of the Institute

The many inquires which have been made regarding the reasons for the formation of the Electric Power Committee and the work which it intends to accomplish, make a statement regarding it appear desirable.

With the natural growth of the Institute, the work which it should cover by the activities of the technical committees naturally resolves itself into a general classification along the following lines:

1. Electric Power. This includes the generation, transmission and distribution of electric power, as illustrated by the work of the public utility. It leaves off its work at the point of application of the power.
2. Industrial Power Applications. This general group takes up the work where the Electric Power Committee leaves off, and includes the industrial power work, the application of electricity to mining and, in general, all classes of motor application other than railroad work.
3. Transportation. The application of electricity to steam railroads, to interurban and urban trolley systems, to trackless trolleys, to electric automobiles, the electric propulsion of ships, etc.
4. The general subject of Illumination.
5. Communication, including Telegraphy, Telephony, Signaling Systems and Wireless.
6. Electrochemical and Electrothermal Applications.
7. Electrotherapeutics.
8. Electrophysics.
9. Special fields of application, such as for domestic use, application of electricity on the farm, in the navy, etc., such as would not come directly under No. 2.
10. The work of records and appraisals, being fundamentally the work in which the public utilities are interested, from the point of view of the Public Service Commissions.
11. The general subject of Economics of Engineering, including the cost of power and the fundamental principles applicable to the work of most of the special committees.
12. Nomenclature.

Starting with the High-Tension Transmission Committee, the number of special committees has increased rapidly and must of necessity continue to do so in the future.

Most engineers are now interested

in a general field, such as electric power, electric transportation, electrophysics, etc., and the efficient working of the organization seems to indicate a grouping along the general lines as outlined above.

In glancing over the list of the Institute committees it will be seen that this has not yet been done to any large extent, and the formation of the Electric Power Committee is the first step in this direction.

In general, the work of a special committee is to handle within the Institute such activities along its own line as may be desired by the members of the Institute in general, and to furnish within the organization such opportunities for the treatment of the subjects in its class as might otherwise be furnished by a separate organization.

The proper working out of organization with the possible size which appears probable in the Institute apparently necessitates the divisions along the lines of the special committees, and also the local organizations now so well developed within the Institute.

Just what the activities of such a special committee should include is necessarily somewhat a matter for discussion, and its working out is most properly along lines of natural growth rather than a forced development.

It is felt that the development of the art in the electric power field should be presented to the Institute through papers under the auspices of this committee, and that such technical and engineering work as is desired by those interested in this field should be offered through this channel. This necessarily means the preparation and presentation of a certain number of papers before the regular meetings of the Institute and before the local Sections. It might also mean the preparation of specifications and standards in conjunction with the other committees of the Institute, and to consider the subjects covered by this committee. The healthy growth which the Institute has had is quite largely by reason of the rapid adaptation of the organization to supply the demands indicated on the part of its membership.

In the work concerning power stations, power generation, transmission and distribution there are many subjects calling for standardization and for such general specifications as can be made.

One year is a very short time in which to accomplish much in a new direction, especially with a committee composed of extremely busy individuals. It is therefore proposed to endeavor to accomplish a more or less clearly outlined field of activity, and to develop somewhat slowly the new functions which such an organization may exercise.

The present magnitude of the Institute and the great diversification in its activities has fortunately been the subject of much consideration at the hands of its present executive, and the developments along lines of better organization may during the present year give every promise of allowing this increase in activity to be met by internal adjustments which will continue the efficiency of the past.

DAVID B. RUSHMORE,
Chairman, Electric Power Committee.

Nominations for Institute Officers for 1914-1915

As provided in Section 18 of the Institute by-laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1914, by the petition or by the separate endorsement in writing, of not less than fifty members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1914. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. **Endorsements may,**

however, be made by letter if the form is not available.

The officers to be elected are: a President and a Treasurer, for the term of one year each, three Vice-Presidents for the term of two years each, and four Managers for the term of three years each.

For the information of members, the full text of Section 18 of the by-laws, governing the proposal of candidates for nomination, is printed below:

"SEC. 18. In addition to the names of the incumbents of office, the Secretary shall publish on 'the form showing offices to be filled at the ensuing annual election in May,' provided for in Article VI, Section 30, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than fifty members, received by the Secretary of the Institute in writing by January 25 of each year.

"The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the January issue of each year's PROCEEDINGS, and shall be reproduced on the form above referred to."

Progress Report of Joint Committee on Inductive Interference

In the PROCEDINGS for May, 1913, an account was given of the organization of the Joint Committee on Inductive Interference, authorized by the Railroad Commission of the State of California to make investigations into inductive disturbances in telephone and telegraph circuits, as a basis for future regulations of the commission.

The Joint Committee has made a general progress report, the first one to give a definite idea of the work of the Committee as being carried out on four important parallels in the Santa Clara Valley. This report has been published in full in *Western Engineering* for November, 1913, page 351, and in the *Journal of Electricity, Power & Gas*, October 4, 1913, page 303. Publication has also been made in *Telephony*, October 18, 1913, page 39.

Directors' Meeting, November 14, 1913

The regular monthly meeting of the Board of Directors of the Institute was held in New York on Friday, November 14, 1913, at 3:30 p.m.

There were present: President C. O. Mailloux, New York; Vice-Presidents A. W. Berresford, Milwaukee, Wis., W. S. Murray, New Haven, Conn., S. D. Sprong, H. H. Barnes, Jr., and C. E. Scribner, New York; Managers F. S. Hunting, Fort Wayne, Ind., N. W. Storer, Pittsburgh, Pa., Farley Osgood, Newark, N. J., C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., W. B. Jackson, Chicago, Ill., B. A. Behrend, Boston, Mass., William McClellan, New York, P. Junkersfeld, Chicago, Ill., L. T. Robinson, Schenectady, N. Y.; Treasurer George A. Hamilton, Elizabeth, N. J.; and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $7,657.29, was ratified.

President Mailloux announced the acceptance by Dr. C. P. Steinmetz of the appointment of Honorary President of the International Electrical Congress, and the acceptance of Dr. E. B. Rosa as Honorary Secretary, which appointments had been authorized by the Board at its October meeting.

President Mailloux further reported that the reorganization of the Executive Committee of the Committee on Organization of the Congress had been completed, as follows: Charles P. Steinmetz, Honorary President of Congress; E. B. Rosa, Honorary Secretary of Congress; H. G. Stott, Chairman; John W. Lieb, Jr., Vice-Chairman; C. O. Mailloux, Chairman, Sub-Committee on International Relations; A. E. Kennelly, Chairman, Sub-Committee on Program; Henry A. Lardner, Chairman, Sub-Committee on Pacific Coast Relations; H. H. Barnes, Jr., Chairman, Sub-Committee on Transportation; George F. Sever, Chairman,

Sub-Committee on Entertainment; Preston S. Millar, Secretary-Treasurer, and Chairman, Sub-Committee on Publicity; F. L. Hutchinson, Secretary A. I. E. E., (ex-officio).

Upon the recommendation of the Meetings and Papers Committee, the Board authorized the following meetings in addition to the New York monthly meetings and the Midwinter and Annual Conventions:

Institute meeting in Washington, D. C., April 10, 1914, under the auspices of the Electrophysics Committee.

Institute meeting in Pittsburgh, Pa., April 23-24, 1914, under the auspices of the Pittsburgh Section and the Committee on the Use of Electricity in Mines.

Institute meeting in Pittsfield, Mass., May 29, 1914, under the auspices of the Pittsfield Section.

Pacific Coast Meeting in Spokane, Washington, September, 1914.

Upon the recommendation of the Board of Examiners, the following action was taken upon pending applications for election and transfer:

Thirty-five applicants were elected Associates.

One hundred and sixty-five students were ordered enrolled.

Elected to the grade of Member: Frederic S. Burroughs, Joseph P. Catlin, Max Hebgen, Thomas J. MacKavanagh, Robert Shand, Thomas A. Sproule.

Transferred to the grade of Member: Evan J. Edwards, L. S. F. Grant, J. D. Hathaway, W. R. Putnam, Henry H. Sinclair, Herbert W. Smith.

Transferred to the grade of Fellow: George A. Campbell, J. Paulding Edwards, J. L. Harper, John P. Mallett, D. B. Rushmore, E. F. Scattergood.

The Special Section Transfer Committee reported two applicants for transfer under the special section of the Constitution, namely, E. T. Goslin, to the grade of Member, and Robert J. Scott, to the grade of Fellow, whose applications had been filed prior to May 1, 1913, and which the committee had examined and found to comply with the special section. Upon motion, these two applicants were transferred to the grades indicated.

President Mailloux referred to the death on November 6 of Sir William Henry Preece, who had been an Honorary Member of the Institute since 1884, and suitable resolutions, previously prepared by a special committee which President Mailloux had appointed, were presented and unanimously adopted.

The President was authorized to appoint three representatives of the Institute upon the recently organized U. S. National Committee of the International Illumination Commission, and $100.00 was appropriated as the Institute's one-third share of the U. S. National Committee's contribution towards the expenses of the Commission. The other bodies represented on the committee are the American Gas Institute and the Illuminating Engineering Society.

The following committee appointments were announced by the President and confirmed by the Board:

Railway Committee: Frank J. Sprague, Chairman, E. B. Katte, Vice-Chairman, A. H. Armstrong, F. W. Carter, Frederick Darlington, W. A. Del Mar, C. E. Eveleth, W. S. Gorsuch, Hugh Hazelton, E. R. Hill, W. S. Murray, A. S. Richey, Clarence Renshaw, Martin Schreiber, N. W. Storer, B. F. Wood.

Committee on Electric Illumination: Clayton H. Sharp, Chairman, Louis Bell, Frank Conrad, J. W. Cowles, E. P. Hyde, A. E. Kennelly, C. F. Lacombe, I. Langmuir, V. R. Lansingh, Preston S. Millar, E. B. Rosa, W. D'A. Ryan, G. H. Stickney.

A. I. E. E. Meeting in New York November 14, 1918

The 288th meeting of the Institute was held in the auditorium of the Engineering Societies Building, New York, on Friday evening, November 14, 1913.

At 8:15 p. m. President Mailloux called the meeting to order. He said that the Society of Automobile Engineers had been invited to attend the meeting, and urged all members of that society who were present to participate freely in the discussion of the subject for the evening. President Mailloux said that as the program for the meeting had been prepared by the Industrial Power Committee of last year, he would ask Mr. John M. Hipple, who was the chairman of that committee, to preside over the discussion.

Mr. Hipple accordingly took the chair, and called upon Mr. Alfred E. Waller to present his paper, *Dynamo Electric Lighting for Motor Cars.* Mr. Alexander Churchward then presented his paper, *Advantages of Clutch Type Generator and Separate Starting and Lighting Units for Motor Cars.* The last of the three papers, *Electrical Equipment of Gasoline Automobiles,* was presented by the author, Mr. Frank Conrad, and the three papers were discussed together.

Those who took part in the discussion were Messrs H. Ward Leonard, Leonard Kebler, Almon W. Copley, A. D. T. Libby, Harold Goodwin, Jr., C. E. Wilson, Benjamin F. Bailey, Kingston Forbes, Alexander Churchward, Alfred E. Waller and Frank Conrad.

At the conclusion of the discussion, a smoker and social gathering was held in the rooms of the Institute on the tenth floor, where light refreshments were served to the members and guests.

Addresses Wanted

Name	Former address.
N. H. Ledford,	Chamber of Commerce, El Paso, Texas.
W.M.B. Macdonald,	Sydney, Nova Scotia.
G. S. Maltha,	Kentland, Ind.
H. E. Nichols,	11½ N. College St., Schenectady, N.Y.
J. F. Robbins,	122 S. 5th Ave., Chicago, Ill.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

Obituary

SIR WILLIAM HENRY PREECE, K. C. B., F. R. S., Hon. Mem. A. I. E. E., former Engineer-in-Chief and Electrician of the British Post Office, one of the highest authorities on telegraphy and telephony, and a pioneer in wireless telegraphy, died at Carnarvon, North Wales, on November 6, 1913. Sir William Henry Preece was born February 15, 1834, near Carnarvon, and was educated at Kings College, London, also studying electricity, at the Royal Institution, under Faraday. In 1852 began his connection with telegraph work, when he entered the office of the late Edwin Clark, then chief engineer of the Electric Telegraph Company. From 1854 to 1856 he acted as assistant to J. Latimer Clark, and in the latter year was appointed superintendent of the southern district. In 1860 he was also appointed by the London and Southwestern Railroad to be superintendent of its electrical system, and in this work did much to perfect railway signaling. In 1870, the government took under its control the telegraph service of the country, and in that year Sir William, then Mr., Preece entered the Post Office service as division engineer for the South of England. Early in his career he had taken out patents for a duplex system of telegraphy. In 1877 he made a visit to the United States with Sir Henry Fischer, which resulted in the introduction into England both of "reading by sound," and of the quadruplex system of telegraphy. In a paper on "Recent Progress in Tele-

graphy" in the British Association report of 1882, Mr. Preece described an experiment he had just made of telegraphing across the Solent, from Southampton to Newport on the Isle of Wight, without connecting wires, the experiment being prompted by a breakdown of the Solent cable. He frankly acknowledged at that time his indebtedness to the ideas of Professor Trowbridge.

"With a buzzer (Theiler's sounder), a Morse key, and thirty Leclanché cells at Southampton", said Mr. Preece, "it was quite possible to hear the Morse signals in a telephone at Newport, and *vice versa*".

In 1884 he began a more systematic investigation, and worked out an electromagnetic system of wireless telegraphy between Lavernock, near Cardiff, and Flatholm, an island in the British Channel, a distance of 3.5 miles, which system was in practical operation for years. Sir William's early wireless apparatus was of a different type from that in use to-day. He found that both speech and telegraphic signals could be transmitted through the earth, or water, by conduction, and he succeeded in using the earth as a medium for wireless messages, whereas modern wireless telegraphy takes place by electromagnetic radiation. Sir William's system of wireless telegraphy was limited to transmission over a few miles only, but it was the first practically successful system.

Sir William was a charter member, in 1871, of the Society of Telegraph Engineers, at London, which later became the present Institution of Electrical Engineers. The first volume of that society's Transactions shows that at its first meeting, he responded to the opening address of Sir William Siemens; also that he was one of the members of its first council. His papers and contributions, not only to the Institution but also to the technical press, extending over half a century, were numerous and important. If collected, they would form a substantial volume. He was twice elected president of the Institution of Electrical Engineers (1880 and 1893). He was elected a fellow of the Royal Society in 1881, was chairman of the Council of the Royal Society of Arts in 1901-02, and took a leading part in a number of scientific and technical societies. His inventions were many, and were chiefly directed to improvements in telegraphy, telephony and railway block-signaling. He was created C. B. in 1894, and was knighted in 1899.

In 1877, Sir William was appointed Electrician to the Post Office Telegraph System, and in 1892 he was also entrusted with the duties of Engineer-in-Chief of that system. He held the combined office until 1899, when he retired, under the age rule, to take up professional engineering practise in conjunction with his two sons and the late Major Cardew, under the firm title of Preece and Cardew, a firm which, still continued as Preece, Cardew and Snell, has carried out much important electrical work.

The personality of the man was remarkable. Endowed with a vigorous constitution, he was an indefatigable worker. He threw himself eagerly, and with manifest delight, into his numerous duties and avocations. When engaged on a task, no difficulty seemed to daunt him, and no opposition to dismay. After an early morning session spent on his own researches, and a long day among the duties of his office, he would perhaps preside until late at night over some scientific society, or go to some distant hall to give a lecture.

In the early days of electric lighting, he eagerly followed the dawning development of the dynamo, and gave great encouragement to the use of electricity in the household, not merely by his official acts, but also by maintaining and equipping an electric light installation in his own home. The installation included a storage battery, which he trained his gardener to care for. In his utterances on the practical side of electric lighting, "*le jardinier de M. Preece*" became a personage of some renown on the European continent, at a time when practical experience in storage battery operation was rare.

When he visited the United States in 1877, he brought back with him the first pair of Bell telephones that entered England. He lectured to both scientific and popular audiences, on this new and wonderful telephonic apparatus, with an enthusiasm and prophetic insight that subsequent events have fully justified.

His talents as a lecturer were great. He had the power to hold the attention and chain the interest of his audience from the moment he stepped upon the platform. His glowing vitality, his directness, and his keen sense of humor, compelled attentiveness; while the simplicity and directness of his address commanded admiration. No scientific lecturer of his day attracted so large an audience. On several occasions, he filled the London Albert Hall.

In his relations with his assistants, he was much beloved. While always ready himself to assume a responsibility, when occasion required, he constantly stimulated initiative in his subordinates. He trained many men for leadership.

In his appearance and mien, there was a power almost leonine in character; while there was also a benignity that enlisted the goodwill of all beholders. His directness of thought and manner never harbored a shadow of pretense, or a suspicion of dissimulation. He never failed to be interested in, and to reflect interest upon, any subject presented to him, and this wide generality of interest was a characteristic of his writings. After returning to England from each of his visits to America in 1884 and 1893, he presented a paper to the Institution of Electrical Engineers summarising his observations on electrical engineering in America. These papers are not only of great historical value, but they also reveal a remarkable versatility and range of technical knowledge, with rare powers of condensation. His genial cordiality made him most popular at the first convention of our American Institute, which he attended, in 1884, at Philadelphia. The first volume of the A. I. E. E. TRANSACTIONS records that he contributed to the discussion on the first paper printed, as well as on a wireless-telegraphy paper. He was then elected an Honorary Member of the Institute, and for a long time he was the only Honorary Member on its lists.

No electrical engineer, coming as a visitor from Great Britain, better appreciated or more doughtily championed the essence and spirit of American engineering. He had many friends in America who loved and honored him. His memory will continue to be cherished by them with reverence and affection. He was one of those rare individuals who, identified with one nation, yet belong, by right of acclaim, to all nations, and in his demise, the electrical engineering fraternity of all lands have lost a friend.

The Board of Directors of the Institute adopted the following resolutions on November 14, 1913:

Whereas: The entire electrical engineering profession has sustained a great loss through the death, on November 6th, 1913, of Sir William Henry Preece, one of its most distinguished votaries, whose professional career covered a period of fifty years of successful endeavor; and

Whereas: Sir William Henry Preece, in September, 1884, attended in Philadelphia, as guest of the Institute, the first convention held by it, and on October the 21st, 1884, was elected the first Honorary Member of the Institute, remaining for many years its only Honorary Member:

Be it resolved: That the Board of Directors of the American Institute of Electrical Engineers hereby places on record its appreciation of his personality, career and attainments, and its sense of the great loss sustained, and

Be it further resolved: That the sympathy and condolence of the Board of Directors of the Institute be extended to the bereaved family, and to the Institution of Electrical Engineers, which honored him twice by electing him President; and

Be it further resolved: That suitably engrossed copies of these resolutions be transmitted to the family, and to the Institution of Electrical Engineers, and that a copy be preserved in the archives of the Institute.

A. E. K.

ASHMEAD GRAY RODGERS, Assoc. A. I. E. E., General Superintendent of the Carborundum Company, of Niagara Falls, N.Y., died on October 23, 1913.

Mr. Rodgers was born in Albany, N.Y., on August 26, 1872. After being graduated from the Hartford, Conn., High School in 1891, he went to Windsor, Conn., and entered the employ of the Eddy Electrical Manufacturing Company. In 1894 he was made foreman of the armature department, and in 1897 was appointed general foreman of the winding departments. On September 27, 1901, while holding this same position, he was elected an Associate of the Institute. After having been in the service of the Carborundum Company for several years, Mr. Rodgers was appointed general superintendent in 1910, which position he occupied at the time of his death.

Recommended for Transfer November 11 and 20, 1913

The Board of Examiners, at its meetings on November 11 and November 20, 1913, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To the Grade of Fellow

ALLEN, C. E., Asst. Manager, D. & S. Dept., Westinghouse E. & M. Co., East Pittsburgh, Pa.

BERRESFORD, ARTHUR W., Vice-Pres. and General Manager, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

CONN, CHARLES F., Asst. Manager, J. G. White Engineering Corporation, San Francisco, Cal.

ELDSDON-DEW, W., Consulting Electrical & Mechanical Engineer, Central Mining & Investment Corporation, Johannesburg, S. Africa.

GRISSINGER, ELWOOD, Consulting Electrical and Mechanical Engineer, Buffalo, N. Y.

HARDING, CHARLES FRANCIS, Professor Electrical Engineering and Director Electrical Laboratories, Purdue University, Lafayette, Ind.

LOZIER, ROBERT TEN EYCK, Vice-President and General Manager, Central Service Corporation, New York, N.Y.

TAYLOR, JOHN BELLAMY, Engineer, Foreign Dept., General Electric Co., Schenectady, N. Y.

To the Grade of Member

DWIGHT, HERBERT BRISTOL, Electrical Engineer, Canadian Westinghouse Co., Hamilton, Ont.

GUNBY, FRANK M., Special Assistant with Charles T. Main, Engineer, Boston, Mass.

HARRIES, GEORGE HERBERT, President, Louisville Gas & Electric Co., Louisville, Ky.

KENNEDY, MATTHEW G., Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

KROGER, FRED H., Radio (Wireless) Engineer, National Electric Signalling Co., Brooklyn, N. Y.

McDOWELL, CLYDE STANLEY, Lieutenant U. S. Navy, Navy Yard, New York, N. Y.

MULLEN, JAMES J., Vice-President, Moloney Electric Co., St. Louis, Mo.

PARKER, LINDSAY R., Engineer of Stations, Toronto Hydro-Electric System, Toronto, Can.

SCOTT, WIRT S., Electrical Engineer, Westinghouse E. & M. Co., East Pittsburgh, Pa.

SMITH, HAROLD HOOPER, Chief of Research Dept., Edison Storage Battery Co., Orange, N. J.

WAY, ASA P., Electrical Engineer, American Railways Co., Philadelphia· Pa.

WYMAN, WALTER SCOTT, Treasurer & General Manager, Central Maine Pwr. Co., Augusta, Me.

Transferred to the Grade of Fellow November 14, 1913

The following were transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on November 14, 1913.

Recommended for Transfer by the Board of Examiners

CAMPBELL, GEORGE A., Research Engineer, American Tel. & Tel. Co., New York, N. Y.

Edwards, J. Paulding, Consulting Engineer, Sacramento, Cal.

Harper, J. L., Chief Engineer, Hydraulic Power Co.; Chief Engineer, Cliff Electrical Distributing Co., Niagara Falls, N. Y.

Mallett, John P., Electrical Engineer, Diehl Mfg. Co., Elizabeth, N. J.

Rushmore, D. B., Engineer, Power & Mining Dept., General Electric Co., Schenectady, N. Y.

Scattergood, E. F., Chief Electrical Engineer, Bureau of Los Angeles Aqueduct Power, Los Angeles, Cal.

Transferred in Accordance with the Special Section of the Constitution

Scott, Robert J., Professor of Engineering, Canterbury College, University of New Zealand, Christchurch, N. Z.

Total 7.

Transferred to the Grade of Member November 14, 1913

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on November 14, 1913.

Recommended for Transfer by the Board of Examiners

Edwards, Evan J., Assistant Engineer, Engineering Dept., National Elec. Lamp Association, Neala Park, Cleveland, Ohio.

Grant, L. S. F., President and Managing Director, Canadian British Insulated Co., Montreal, Que.

Hathaway, J. D., Superintendent, Imperial Wire & Cable Co., Ltd., Montreal, Que.

Putnam, W. R., Electrical Engineer and General Manager, Dakota Power Co., Rapid City, S. D.

Sinclair, Henry H., Vice-President, Centinella Improvement Co., Los Angeles, Cal.

Smith, Herbert W., Manager Boston Office, Ft. Wayne Electric Works of Ft. Wayne, Indiana, Boston, Mass.

Transferred in Accordance with the Special Section of the Constitution

Goslin, E. T., Chief Electrical Engineer, Corporation Tramways, Glasgow, Scotland.

Total, 7.

Members Elected November 14, 1913

Burroughs, Frederic S., Chief Engineer, Public Service Commission of Washington, Olympia, Wash.

Catlin, Joseph P., Electrical Engineer, General Electric Co., Pittsfield, Mass.

Hebgen, Max, Vice-President and General Manager, Montana Power Co., Butte, Mont.

MacKavanagh, Thomas J., Instructor in Electrical Engineering, Technical Institute, Shawinigan Falls, Quebec.

Shand, Robert, Electrical Engineer, General Electric Co., Lynn, Mass.

Sproule, Thomas, Assistant Engineer, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

Total 6.

Associates Elected November 14, 1913

Ames, Maurice Patterson, Superintendent, Testing Dept., Burk Electric Co.; res., 115 W. 8th St., Erie, Pa.

Bourke, Rowland L., Instructor Mechanical Drafting and Applied Mechanics, New York Electrical School; res., 144 W. 12th St., New York, N.Y.

Bowen, Oscar Sibley, Telephone Engineer, S. H. Conch Co., Boston; res., 34 Apthorp St., Wollaston, Mass.

Boykin, Richard M., Engineer, Washington-Oregon Corporation; res., 685 Irving St., Portland, Ore.

Buzzell, Robert Knight, Electrician, Hotson & Gillies; res., 2948 Carolina St., Vancouver, B. C.

Dorting, Emil E., Assistant Chief Tester Edison Storage Battery Co., Orange; res., 10 Orange St., Bloomfield, N. J.

ECKBO, OLAF LAACHE, Electrical Engineer, Ebro Irrigation & Power Co., Barcelona, Spain.

EVES, WILLIAM, 3RD, Electrical Engineer, Americal Vulcanized Fibre Co.; res., 301 W. 18th St., Wilmington, Del.

FLEMING, ELLIOTT, Electrician, Invercargill Tramways, Tramway Power Station, Invercargill, New Zealand.

FRANCIS, ROY WILLIAM THOMPSON, Engineer on Transformers, General Electric Co., Lynn; res., 5 Neilson Ave., Everett, Mass.

GEE, HARRY ERNEST, Purchasing Agent, Midland Construction Co. Ltd., 537 Confederation Life Bldg., Toronto, Ont.

GILBERT, JOHN JOSEPH, Instructor of Electrical Engineering, Armour Institute, Chicago, Ill.

HENNING, C. I. B., Chief Ballistic Engineer, E. I. du Pont de Nemours Pdr. Co., Henry Clay; res., 2006 Woodlawn Ave., Wilmington, Del.

HOCKLEY, WILLIAM, Industrial Power Agent, Western Canada Power Co. Ltd; res., 436 King Edward Ave. E., Vancouver, B. C.

HUSON, SIDNEY WALPOLE, Electrician, Hotson & Gillies; res., South Hill P. O., Vancouver, B. C.

KELLY, WILLIAM FITZGERALD, Vancouver District Manager, Canadian Tungsten Lamp Co. Ltd., 365 Water St., Vancouver, B. C.

KENYON, GEORGE FREDERICK, Electrical Engineer, Hotson & Gillies; res., 1837 Morton Ave., Vancouver, B. C.

KIRBY, LEROY JENNINGS, General Engineering Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 207 Mifflin Ave., Wilkinsburg, Pa.

KIRKWOOD, MACLEAN, Engineering Dept., American Telephone & Telegraph Co., 15 Dey St., New York, N.Y.

KNOEPPEL, FRANK WESLEY, Chief Electrician, Cyphers Incubator Co.; res. 523 Glenwood Ave., Buffalo, N. Y.

LANGDON-DAVIES, WALTER, Electrical Engineer, B. C. Electric Railway; res., 187-23rd Ave. W., Vancouver, B. C.

LAUFFER, CHARLES A., Medical Director, Westinghouse Electric & Mfg. Co., 521 Franklin Ave., Wilkinsburg, Pa.

LEWIS, WILLIAM PAUL, Electrical Installation, Citizens Electric Co., Hot Springs, Ark.

LINDSAY, SHERWOOD C., Electrical Engineer, Seattle Electric Co.; res., 3017 45th Ave., S.W., Seattle, Wash.

LOCKWOOD, ALVAH M., Transmission Line Construction, 618 Camden St., San Antonio, Tex.

McNEILL, RALPH WALDO, Electrician, Utah Copper Co., Magna Plant, Garfield, Utah.

MILLIGAN, FRANK GAUDARD, Operating Engineer, 811 6th Ave. N., Seattle, Wash.

MILNOR, JOSEPH WILLARD, Engineering Assistant, Western Union Telegraph Co., Room 509, 195 Broadway, New York, N. Y.

MORROW, LESTER WILLIAM WALLACE, Assistant Professor of Electrical Engineeering, University of Oklahoma, Norman, Okla.

MURPHY, WILLIAM JAMES, Chief Electrical Inspector, City of Edmonton. Electric Light & Power Dept., Edmonton, Alta.

NORTHRUP, EDWIN S., Electrical Engineer, State Architect's Office, Albany, N. Y.

OTIS, CLARENCE WENDELL, Commercial Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 760 Franklyn Ave, Wilkinsburg, Pa.

SANDS, WILLIAM HAMILTON, JR., Engineering Inspector, Central District Telephone Co., 1306 Fulton Bldg., Pittsburgh, Pa.

STEWART, DAVID W., Engineer, Waipori Falls Power Station, Dunedin, N. Z.

THORPE, FRANK J., Chief Electrician, Empire Limestone Co., Sanborn, N.Y.

Total 35.

Students Enrolled, November 14, 1913

5978 Fetherstoh, J. M., Univ. of Illinois.
5979 Roush, W. A., Highland Park Coll.
5980 Billheimer, C. R., Ohio Northern University.
5981 Lay, N. W., Ohio Northern Univ.
5982 Mittenthal, N. J., Stanford Univ.
5983 Wilson, G. O., Stanford University.
5984 Bussert, L., Stanford University.
5985 Ekstrand, C. E., Lehigh Univ.
5986 Dutton, B. E., Colorado Agri. Col.
5987 Anderson, H. H., Univ. of So. Cal.
5988 Stedman, H.E., Highland Park Coll.
5989 Harty, R. V., Highland Park Coll.
5990 Hall, R. B., Highland Park Coll.
5991 Arp, W. B., Armour Inst. of Tech.
5992 Johnson, E.E., Kentucky State Univ.
5993 Cottrell, R.B., Kentucky State Univ.
5994 Harp, C. C., Kentucky State Univ.
5995 Townsend, R.P., State Univ. of Ky.
5996 Gaither, D. M., State Univ of Ky.
5997 Hedges, H. B., State Univ. of Ky.
5998 Shelton, H. R., State Univ. of Ky.
5999 Morgan, D. T., State Univ. of Ky.
6000 Howard, T. D., State Univ. of Ky.
6001 Gayle, G. W., State Univ. of Ky.
6002 Bennett, A. R., State Univ. of Ky.
6003 Masters, H. R., State Univ. of Ky.
6004 Carrithers, W. S., State Univ. of Ky.
6005 Thornton, R. T., State Univ. of Ky.
6006 Howell, C. W., Univ. of Michigan.
6007 Bocker, L. M., Univ. of Kansas.
6008 Hansen, H. C., Univ. of Kansas.
6009 Washburn, G. A., Univ. of Kansas.
6010 Sumner, A. W., Univ. of Penn.
6011 Smith, L. C., Univ. of Penn.
6012 Small, J. C. M., Univ. of Penn.
6013 Shearer, A. A., Univ. of Penn.
6014 Sheffler, M., Univ. of Penn.
6015 Sigman, J., Univ. of Penn.
6016 Shaw, A. W. T., Univ. of Penn.
6017 Roberts, S., Univ. of Penn.
6018 Pennock, F. E. Jr., Univ. of Penn.
6019 Plass, C. W., Univ. of Penn.
6020 Ouerbacker, S. H., Univ. of Penn.
6021 Mahan, J. H., Univ. of Penn.
6022 Noe, E. T., Jr., Univ. of Penn.
6023 Noppel. E. P., Univ. of Penn.
6024 Oetinger, H. W., Univ. of Penn.
6025 Bishop, E. A., Univ. of Penn.
6026 Corral, R., Univ. of Penn.
6027 Doolittle, C. M., Univ. of Penn.
6028 Egee, G. B., Univ. of Penn.
6029 Epstein, S., Univ. of Penn.
6030 Herr, F. L., Univ. of Penn.
6031 Kirk, J. B., Univ. of Penn.
6032 Adler, A., Univ. of Penn.
6033 Beatty, L. B., Univ. of Penn.
6034 Gillette, E. H., Univ. of Mich.
6035 Hermann, A. H., Univ. of Mich.
6036 Wells, C. A., Univ. of Mich.
6037 Drake, H., Univ. of Mich.
6038 Sewell, G. L., Univ. of Mich.
6039 Erley, W. A., Univ. of Mich.
6040 King, E. D., Univ. of Michigan
6041 Hurme, E. A., Univ. of Michigan.
6042 Gibell, G. H., Univ. of Michigan.
6043 Cross, W. C., State Univ. of Ky.
6044 Hoke, R. K., Bucknell University.
6045 Mieczkawski, T.K., Armour Inst. of Tech.
6046 Seeberger, H.F., Armour Inst. Tech.
6047 Imes, O. S., Univ. of Illinois.
6048 Blaker, E. C. T., State Univ. of Ky.
6049 Heuthorno, H. F., Case School Applied Science.
6050 Gordon, C. P., Univ. of Wash.
6051 Beaver, G. L., Stanford Univ.
6052 Izhuroff, B. A., Univ. of Wash.
6053 Parsons, S. S., Stevens Inst. Tech.
6054 Marcy, C. G., Univ. of Wash.
6055 Vernam, G.S., Worcester Poly. Inst.
6056 Parmenter, R. J., Bucknell Univ.
6057 McKelvey, C. F., Univ. of Colo.
6058 Redding, F. A., Univ. of Colo.
6059 Sweitzer, L. E., Univ. of Colorado.
6060 Soderstrom, C. A., Univ. of Colo.
6061 Charlton, J. R., Armour Inst. Tech.
6062 Adamson, J. F., Armour Inst. Tech.
6063 Wright, C. F. Armour Inst. of Tech.
6064 Paszkiewicz, J. A., Armour Inst. Tech.
6065 Cheeny, R. C., Case Sch. App. Sci.
6066 Kerr, H. H., Univ. of Colorado.
6067 Watts, H. T., State Univ. of Ky.
6068 Strong, H. G., State Univ. of Ky.
6069 Schoeufeld, D. L., Penn. St. Coll.
6070 Scharf, R. W., Penn. State College.
6071 Thwing, E. P., Univ. of Wash.
6072 Kelly, G. E., State Univ. of Ky.
6073 Dobbins, H.C., Ohio Northern Univ.
6074 Stavert, R. E., McGill University.
6075 Wolf, W. H., Univ. of Arkansas.
6076 Hayden, E. B., State Univ. of Ky.
6077 Butz, G. R., Penn. State College.

6078 Smith, H. R., Ohio Northern Univ.
6079 Jones, A. B., Wash. State College.
6080 Schott, W. F., Ohio Northern Univ.
6081 Lowe, R. E., Ohio Northern Univ.
6082 Bigelow, P. T., Univ. of Wash.
6083 Collins, A. J., Univ of Arkansas.
6084 Swanson, F. A., Armour Inst. Tech.
6085 Gazda, A. A., Cornell University.
6086 Huber, H. L., Cornell University.
6087 Kehl, R. J., Cornell University.
6088 Robinson, G. D., Cornell Univ.
6089 Ts'en, M. K., Cornell University.
6090 Izumi, I., Univ. of Washington.
6091 Daubenspeck, L. L., Ohio Northern University.
6092 Douglas, G. R., Cornell University.
6093 Kent, P. J., Cornell University.
6094 Rasch, G. A., Cornell University.
6095 Reese, J. L., Cornell Univeristy.
6096 Saunders, G. G., Cornell Univ.
6097 Shaw, S. E., Cornell University.
6098 Stevens, H. W, Cornell University.
6099 Williamson, G. M., Cornell Univ.
6100 Webber, L. H., Mass. Inst. Tech.
6101 Winder, W. A., Univ. of So. Cal.
6102 Powell, A. E., Univ. of Wisconsin.
6103 Bessesen, B. B., Univ. of Wash.
6104 Cantrell, L. V., Univ. of Kansas.
6105 Bangar, A. H., Ohio Northern Univ.
6106 Swift, S. J., Yale University.
6107 Thorpe, W. A., Yale University.
6108 Gracey, A. L., Univ. of Penn.
6109 Maull, W. R., Univ. of Penn.
6110 Wade, W. H., Univ. of Penn.
6111 Gollub, L., Univ. of Pennsylvania.
6112 Burton, W. E., Univ. of Colorado.
6113 Gravenstreter, H. R., Case School of Applied Science.
6114 Bates, W. H., A. & M. Coll of Tex.
6115 Stribling, S. R., A. & M. Coll. of Tex.
6116 Kiesling, J. A., A. & M. Coll .Tex.
6117 Hill, S. S., A. & M. Coll. of Texas.
6118 Biggers, C. A., A. & M. Coll. of Tex
6119 Parsons, C. W. S., Stevens Inst. Tech.
6120 Andrews, R. B., Stanford Univ.
6121 Marich, W. D., Stanford Univ.
6122 Lang, L. A., Stanford University.
6123 Richards, R. E., Stanford Univ.
6124 Cole, C. A., Stanford University.
6125 Alden, C. R., Ohio Northern Univ.
6126 Smith, B. H., Univ. of Oregon.
6127 Stuart, B. O., Washington St. Coll.
6128 Goldsmith, E. D., Univ. of Wash.
6129 Horiuchi, S., Stanford University.
6130 Nakamura, Y., Stanford Univ.
6131 Ebling, J. N., Pratt Institute.
6132 Ross, A. C., University of Toronto.
6133 Winter, F. B., McGill University.
6134 Suen, S. T., University of Wis.
6135 Steiner, L. E., Ohio Northern Univ.
6136 Roches, V. D., Univ. of Michigan.
6137 Anderson, E. T., Univ. of Mich.
6138 Smiley, G. W., Univ. of Michigan
6139 Ernest, R. D., Univ. of Michigan.
6140 Baker, W. D., Univ. of Michigan.
6141 Baker, B. A., Univ. of Michigan.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 30, 1913.

Aldworth, E. L., Grand Rapids, Mich.
Atkinson, K., Columbia, Mo.
Atkisson, E. J., Washington, D. C.
Barton, F. S. (Member), Nunda, N.Y.
Billingsley, F. N., Pittsfield, Mass.
Brennan, W. D., Cheyenne, Wyo.
Broom, B. A., Sioux City, Iowa.
Burr, H. L., Brooklyn, N. Y.
Butcher, X. M., Gatun, Canal Zone.
Butterworth, A. C., Duluth, Minn.
Carr, W. de L., Philadelphia, Pa.
Cheney, M. E., Seattle, Wash.
Cleveland, W. D., Portland, Ore.
Connally, J. G. M., Vancouver, B. C.
Connell, E. L., St. Louis, Mo.
Dean, P. P. (Member), New York, N.Y.
Dershem, E., Schenectady, N. Y.
Dexter, H. E., Schenectady, N. Y.
Dover, A. T., London, England.
Ducharme, F. L., Boston, Mass.
Dunn, H. A., Necaxa, Puebla, Mexico.
Eames, C. H. (Member), Lowell, Mass.
Edgell, W. T., Jr., Pittsfield, Mass.
Elftman, J. D., St. Joseph, Mo.
Everett, F. D., New York, N. Y.

Field, H. H., New London, Conn.
Fisher, R. B., Schenectady, N. Y.
Frank, C. F., Schenectady, N. Y.
Fryer, H., Boston, Mass.
Goebert, E. C., Philadelphia, Pa.
Griffitts, L. C., Aurora, Ill.
Haggen, E. A., Vancouver, B. C.
Harbin, G. F., Washington, D. C.
Harvey, R. J., Preston, England.
Hebbert, C. E., Newark, N. J.
Hehnreich, L. W., St. Louis, Mo.
Helhake, W.O. (Member), Springfield, Ill.
Hentz, R. A., Philadelphia, Pa.
Hillegass, H. H., Newark, Del.
Hull, F. D., Chicago, Ill.
Humphrey, H. K., Schenectady, N. Y.
Hutchins, R. A., Schenectady, N.Y.
Ito, K., Tokyo, Japan.
Kerrick, H. S., Ft. Hamilton, N. Y.
Kohl, G. H., Prince Rupert, B. C.
Kurie, C. W., Colorado Springs, Colo.
Kutner, S. D., New York, N. Y.
LaMoree, C. D., Los Angeles, Cal.
Lindall, C. R., Iron River, Mich.
Locke, D. J., Worcester, Mass.
Lohse, A. C., Chicago, Ill.
Long, C. C., Grace, Idaho.
Miller, L. G., Boston, Mass.
Mittag, A. H., Schenectady, N. Y.
Montsinger, V. M., Pittsfield, Mass.
Moore, H. J., Cleveland, Ohio.
Oakes, A., Detroit, Mich.
Ottman, R. E., Milwaukee, Wis.
Pascoe, H. N., Worcester, Mass.
Penn, M., Schenectady, N. Y.
Powers, A. R., Potsdam, N. Y.
Rennie, W. M., Ann Arbor, Mich.
Reynolds, O. B., Otago, N. Z.
Saxon, L. (Member), New York, N. Y.
Schaefer, C. C., Philadelphia, Pa.
Schmauder, W. G., Waco, Texas.
Spratt, W. C., Schenectady, N. Y.
Steere, L. E., Jr., St. Louis, Mo.
Sugiyama, K., Tokyo, Japan.
Swoboda, H. O., Pittsburgh, Pa.
Tawell, T. A., Schenectady, N. Y.
Thiele, E. J., Schenectady, N. Y.
Thompson, A. C., Toorack, Victoria, Aus.
Tivey, J. P., Schenectady, N. Y.
Trott, A., Vancouver, B. C.
Walker, A. S., Prince Rupert, B. C.
Ward, A. T., Chrome, N. J.
Ward, J. E., Schenectady, N. Y.
Wenger, T. L., New York, N. Y.
Wheeler, F. S., Schenectady, N. Y.
Woodman, F.W., Pinawa, Manitoba, Can.
Wooster, R. N., Schenectady, N. Y.
Young, C. N., Schenectady, N. Y.
Total, 83.

Philadelphia Section Meetings

The Philadelphia Section of the Institute has issued a complete program of the meetings to be held during its 1913-1914 season. Three meetings have already been held, beginning with the Institute meeting in Philadelphia on October 13. The condensed program which follows gives the dates of future meetings and titles of papers to be presented.

December 4, 1913. "Some Present-Day Metallurgical Processes," by D. A. Lyon. (Joint meeting with the Franklin Institute.)

December 8, 1913. "Railway Car Lighting," by G. E. Hulse; "Brightness Measurements vs. Illumination Measurements," by Herbert E. Ives; "The Mercury Vapor Quartz Lamp," by M. B. Buckman. (Joint meeting with the Philadelphia Section, Illuminating Engineering Society.)

January 12, 1914. "Coupled Circuits, or the Problem of the High-Frequency Transformer in Wireless Telegraphy," by W. S. Franklin.

February 9, 1914. "Business Training for the Engineer." Discussion by Alexander C. Humphreys, Theodore I. Jones, Ralph D. Mershon. (Joint meeting with the Philadelphia Section, American Society of Mechanical Engineers.)

March 9, 1914. "Applications of Electricity in the Army," by L. S. Ryan; "Applications of Electricity in the Navy," by J. G. Tawresey; "The Manufacture of Electrical Apparatus for the Army and Navy," by Maxwell W. Day.

March 18, 1914. "The Problem of Electric Conduction," by Edwin F. Northrup. (Joint meeting with the Franklin Institute.)

April 13, 1914. "The Loading of

Telephone Circuits," by H. Mouradian; "Some Phases of the Operation of a Telephone Plant," by H. C. Kunkel; and a third paper on telephony, to be announced later.

April 23, 1914. "Recent Developments in Hyperbolic Functions as Applied in Electrical Engineering," by A. E. Kennelly. (Joint meeting with the Franklin Institute.)

May 11, 1914. "Industrial and Mining Locomotives." "The Battery Locomotive," by Joseph S. Tracy; "The Trolley Type Locomotive," by K. Andrew; "Contactor or Sectional Systems," by E. F. Bush.

June 8, 1914. "The Society for Electrical Development, and Its Purposes," by J. M. Wakeman.

The meetings, with the exception of the joint meetings with the Franklin Institute, are held at the Engineers' Club.

Past Section Meetings

Baltimore

The October meeting of the Baltimore Section was held in the Physical Laboratory of the Johns Hopkins University, on Friday evening, October 31. Mr. W. S. Murray, formerly electrical engineer of the New York, New Haven and Hartford Railroad, gave an interesting talk on "The Electric Operation of Railway Tunnels and Terminals." The talk was particularly appreciated at this time in view of the agitation in favor of such electrification in Baltimore. Mr. Murray brought out clearly both the advantages and difficulties of such electrification.

The talk was illustrated by a number of lantern slides showing nine methods of construction, particularly as to overhead work.

Ninety-two members and visitors were present. Chairman J. B. Whitehead presided.

Boston

The first meeting of the Boston Section for the 1913-1914 season was held in the auditorium of the Engineers Club, No. 2 Commonwealth Avenue. October 30, at 8:00 p.m.

Mr. F. C. Morton of the Crocker-Wheeler Company gave an interesting talk on "Western Industries as Seen by an Electrical Engineer". Mr. Morton's talk was accompanied by lantern slides showing the different applications of electrical energy in the West. Mr. Morton was at one time sales engineer in the Rocky Mountain district and his experiences while there made him well qualified to speak on this subject.

In all, there were about sixty members present. Chairman N.J. Neall presided.

Cleveland

A meeting of the Cleveland Section was held on October 22 at the Electric Controller and Manufacturing Company, when Mr. F. R. Fishback of that company presented a paper on "Uses of Electricity in the Manufacture of Steel". Mr. A. C. Eastwood presided. The total attendance was 54.

Detroit-Ann Arbor

A meeting of the Detroit-Ann Arbor Section was held on October 31 at the Griswold House in Detroit. After an informal dinner, a number of short addresses were made by the executive officers of the Section, outlining plans for the work of the coming year. At 9 p.m., after a social time had been enjoyed, a paper was presented by Mr. Chester L. Dows, of the National Electric Lamp Association, concerning the characteristics and development of the new high-efficiency nitrogen-filled tungsten lamp. The paper was freely discussed, with particular reference to the proper fields of application for the lamp, and its commercial effects and possibilities.

There being at present only about fifty members of the Institute in the vicinity of Detroit and Ann Arbor, which is not enough to insure a strong attendance at every meeting of the Section, it was decided to initiate a vigorous compaign to obtain new members for the Institute and the Sec-

tion. Professor H. H. Higbie, of the University of Michigan, was appointed chairman of the program committee, and some interesting addresses are in preparation.

Professor A. R. Sawyer, chairman of the Section, presided at the meeting.

INDIANAPOLIS-LAFAYETTE

The October meeting of the Indianapolis-Lafayette Section was held at the Chamber of Commerce Building, Indianapolis, on Friday evening, October 10. Mr. Lewis L. Tatum, assistant chief engineer of the Cutler-Hammer Company, presented a paper on "Industrial Motor Control". Mr. Tatum showed how control systems were always a compromise between safety, reliability, and economy, emphasizing that safety came first. He pointed out the tremendous range of the subject of control, showing how the controller must be designed to suit the particular work and the particular motor, and making a plea that the motor for any given control system be also adapted for the particular work it is to do. He also showed a number of lantern slides, illustrating the different features involved in controller design.

Forty-three members and visitors were present at the meeting. Chairman O. S. More presided.

LOS ANGELES

The Los Angeles Section held a meeting on October 23, in the Music Hall of the Blanchard Building, at which Mr. Ernst M. Schmelz presented a paper on "The Manufacture of Steel by Electricity." This was an informal paper describing the installation and operation of an electrical steel furnace for the Warman Steel Casting Company at Redondo Beach, California.

Chairman E. R. Northmore presided at this meeting, at which the total attendance was 73.

LYNN

On October 22 the Lynn Section held a meeting in Burdett Hall, at which the attendance was 218.

In his opening remarks, Chairman E. R. Berry stated that the membership now numbered 600, about 50 more than the previous high-water mark.

The speaker of the evening was Mr. C. W. Stone, manager of the Lighting Department, General Electric Company, who traced the developments in the "Generation and Distribution of Electrical Energy by Public Utility Companies", referring to the conditions existing at the time when direct currents only were used, leading up to the later period of the introduction of single-phase alternating currents for lighting and the special advocacy by the General Electric and Westinghouse Companies of three-phase and two-phase systems, respectively, for power distribution. Mr. Stone further compared the conditions in this country with those in England. In the latter country, the railways have their own power, with a poor load factor, and the lighting systems have a high load factor. The speaker made the point that this combination was not conducive to the most efficient operation, and stated his belief that in order to get the cheapest and best possible service there must be a monopoly to combine the various loads of different characteristics and obtain thereby a better load factor, that is, a steady and uniform output. Mr. Stone stated that he knew of no other commodity that had gone down so much in cost as electrical energy and looked for the reduction in the not distant future to reach as low as five cents per kilowatt-hour, or less. The speaker emphasized the fact that this was an age of specialization, and that, therefore, railroads should not be power producers, as they are transportation experts, while the central station companies are experts in power producing.

Mr. Stone discussed the advantage which we in this country have had in adapting ourselves to the developments and improvements in light and power distribution, stating that, as in this country we have almost universally adopted 110-120 volts for use on lamp

load and have used the three-wire system, we have been enabled to accommodate ourselves to the various changes, whereas in England, where they were using 250 volts for lighting and 500 volts for railway work, it has been more difficult for them to make the necessary changes during the transition period from the use of the carbon to the introduction of the nitrogen lamp, it being necessary to use compensating transformers, etc.

The next meeting of the Lynn Section was held on November 5, at the General Electric Works in West Lynn. Chairman E. R. Berry presided, and the meeting was attended by 218 members and 23 visitors.

Mr. David B. Rushmore, engineer of the Power and Mining department, General Electric Company, Schenectady, addressed the meeting on "Some Phases of Power Transmission Work." Mr. Rushmore was introduced by Professor Elihu Thompson. With the assistance of a large number of lantern slides, Mr. Rushmore succeeded in giving his audience a very clear conception of the wonderful advancement which has occurred in hydroelectric development during comparatively recent years.

Mr. Rushmore showed a waterpower map of the United States and gave interesting statistics of the hydroelectric plants now in use and in process of construction in various parts of the country. In California, New England, North and South Carolina, Michigan and Arizona the most striking examples are to be found. The largest single plant is to be seen at Keokuk, Iowa, where 300,000 h.p. is to be generated, and which is to furnish power to St. Louis. This installation is being completed at a cost of $19,000,000, and is being built on lines designed to last for all time.

The speaker referred to the importance which plants of this character would assume when the coal supply becomes exhausted, and dwelt at some length on questions much discussed, relative to the respective merits of different forms of power house design. Various illustrations of transformers used in these gigantic power schemes, as well as of aluminum lightning arresters, were projected on the screen.

Madison

The meeting of the Madison Section on October 16 was held jointly with the local section of the American Society of Mechanical Engineers and the Civil Engineering Society of Wisconsin. Certain members of these organizations had recently returned from Europe, and arrangements were made to have them present their impressions of European engineering practise and economic conditions. Professor L. S. Smith described city planning as carried out principally in Germany and England, and showed the advantages to be gained, socially and economically, by careful preparation of city plans for future development. Professor H. J. Thorkelson showed a large number of lantern slides and described the trip through Germany of the members of the American Society of Mechanical Engineers who visited Germany this summer at the invitation of the Verein Deutscher Ingenieure. Professor R. C. Disque dealt with impressions received of the characteristics of the German people and of the effects of these upon the industrial conditions. Professor A. G. Christie spoke of some of the latest developments in prime movers, both in England and in Germany, and touched upon the labor conditions in these countries.

The program was a long one but was much enjoyed by those who were present, as the conditions abroad are so different from those found in our own country.

The meeting was held in the Engineering Building of the University of Wisconsin, and was presided over by Chairman Edward Bennett of the Madison Section A.I.E.E. The total attendance was 50.

Mexico

A meeting of the Mexico Section was held at Sylvain's Restaurant in Mexico City on October 30, the first meeting of the 1913-1914 season. The meeting was attended by 24 members and 26 visitors.

Following the dinner, the business before the Section was taken up, and a program for the year was adopted. The paper of the evening was then presented by Mr. S. A. Rapier, entitled "How Incandescent Lamps as They Improve in Efficiency Will Affect Central Station Revenue". Mr. Rapier pointed out that although the cost of almost all other things is getting higher, all over the world, electricity for light and power has been continually getting cheaper, and will continue to do so, with improvements in generating and transmission and in the final consuming apparatus and appliances. Mr. Rapier said that the best commercial incandescent lamp in use today has an efficiency of about seven per cent, the rest of the energy being lost in producing heat rays that do not give light. A new incandescent lamp has been developed which will have an efficiency of about 15 per cent. Mr. Rapier discussed the effect of such improvements on central station revenues.

Upon the conclusion of the paper, the discussion was participated in by many of the engineers present.

Milwaukee

The Milwaukee Section of the A. I. E. E. held a joint meeting with the Engineers' Society of Milwaukee at the Plankinton House, on September 17. As this was the first meeting of the season, no formal program was provided and the members and visitors enjoyed two informal talks, and a buffet luncheon.

Mr. R. C. Newhouse commented upon engineering methods employed in Europe, as observed by him on an extended trip.

Mr. A. R. Schmidt gave an interesting comparison between steam railroad and street railway transportation in America and in Germany. The recounting of numerous personal experiences and observations while traveling in America and in Germany emphasized the speaker's points.

The total attendance at this meeting was 90. Mr. E. P. Worden presided.

The next joint meeting of the two societies was held on October 8 at the same place. Chairman E. P. Worden of the Engineers' Society presided.

Professor A. G. Christie discussed the results of very exhaustive tests made in the laboratories of the University of Wisconsin upon various forms of Pitot tubes. The speaker showed, from the results of numerous carefully executed laboratory tests, that the method of obtaining the static pressure is of great importance, and that the use of a so-called pezometer ring improves the accuracy of all forms of Pitot tubes, as it provides an improved means of obtaining the static pressure. Some types of tubes showed errors of at least ten per cent ordinarily, whereas with the addition of a pezometer ring the error was reduced to a fraction of one per cent. In all the experiments the standard measurements were obtained by the use of a Thomas meter. The lecture was illustrated by the use of numerous slides.

Professor Christie then gave a brief discussion of various recent foreign developments in steam power apparatus, illustrating his talk with lantern slides.

The meeting was attended by approximately ninety persons, and was followed by a buffet luncheon.

The regular joint meeting of the Milwaukee Section of the A. I. E. E., the Milwaukee Section of the A. S. M. E. and the Engineers' Society of Milwaukee was held at the Plankinton House on November 12. Chairman Emil Vilter of the Engineers' Society presided.

Mr. I. M. Clicquennoi, engineer for the Universal Portland Cement Com-

pany, gave a talk on "A Study of Concrete Aggregates and Their Relation to Successful Concrete Work." The speaker emphasized the importance of the proper selection of aggregates and stated that failures of concrete work, although ordinarily attributed to "poor" cement, are often due to impurities in the aggregates or to improper grading, or to both.

In discussing the impurities in aggregates, the speaker stated that these are usually in the form of dust, clay, loam, oxides and vegetable matter. Dust covering the surface of the aggregates may prevent a good bond and thus greatly reduce the strength of the concrete.

Clay, if it coats the separate particles of sand, stone and gravel, is injurious in the same manner, although if the particles of clay are separate they may simply serve to fill voids in the aggregates and thus will not be harmful. Loam, oxides and vegetable matter are injurious in much the same manner. Moisture in the aggregate is injurious as it tends to make the cement or sand ball up and thus prevents a perfect bond.

In the discussion of proper grading, the speaker stated that the object is to fill all voids, thus making the concrete impervious to moisture and of great density and strength. Grains of sand should be of various sizes in order to fill a large proportion of the voids, and, in general, a good practical rule is to use one-half as much sand as gravel. As an illustration of the necessity of having sand of various sized grains, it was stated that spheres of equal size would have approximately 26 per cent voids.

It was stated that so-called "sharpness" of grains tends to produce greater voids than smooth grains which pack more closely. Attention was also called to the fact that large grains of sand have relatively less surface to be covered by the cement and hence sand of this kind is economical.

The talk was illustrated with numerous lantern slides.

The meeting was attended by approximately 100 persons, and was followed by a buffet luncheon.

Minnesota

A regular monthly meeting of the Minnesota Section was held in the auditorium of the main Engineering Building of the State University on October 20. The meeting was called to order at 8:15 p.m. by Chairman W. T. Ryan.

A report on the Cooperstown Convention was made by Mr. Arthur L. Abbott, who was the delegate of the Minnesota Section. A paper was then presented by Mr. R. M. Stanley, engineer of the H. M. Byllesby Company, on "Generating and Distributing Systems of the Consumers Power Company of the Twin Cities." The speaker illustrated his remarks with photographs and drawings projected upon the screen. A discussion of the paper followed, Dean Shannahan, Mr. Nessley, Mr. Lundquist, Professor Ryan and others taking part.

The program was concluded by a moving picture representation of the building of a modern concrete dam.

Pittsburgh

The Pittsburgh Section held a meeting in the Oliver Building on October 14, at which Mr. H. O. Swoboda presented a paper on "The Design, Construction and Operation of Electric Heating Apparatus."

After discussing the physical phenomena pertaining to the generation of heat by electricity, the paper discussed the development of non-oxidizing material for the heating element of electric heating devices, and the temperatures which could safely be attained with various materials, such as nickel-chromium alloy, platinum, carbon treated with silicon vapor, tungsten wire imbedded in proper insulating material, etc. Induction type heaters were discussed, and also the production of temperatures above 700 to 1200 deg. cent., as in the electric furnace. The characteristics

of the essential materials used in heating apparatus, having respectively refractory, heat insulating, electrical insulating and heat conducting properties, were then considered, and their application and use in commercial types of heating apparatus and electric furnaces was described.

After discussing the inherent efficiency and cost of operating electric heating apparatus, the paper took up a number of interesting points relative to the economics of electric heating, the latter bringing forth a very interesting discussion.

In discussing the comparative cost of electric heat as against gas and coal, Mr. T. S. Perkins pointed out that arguments in favor of electric heating must discriminate between applications where the electric method is a convenience and where it is a luxury. For example, to cook a 75-cent steak at a cost of 3 cents makes of the electric broiler a convenience, or to prepare say 7 cups of coffee at a cost of 1 cent makes of the electric percolator a convenience, whereas, to cook 10 cents' worth of cereal at a cost of 5 cents for power places the electric method in the light of a luxury. While the cost of operating the electric iron is relatively high compared with the cost of gas for heating the ordinary irons, the fact must be considered that many times more heat is wasted in ironing by gas than is required to heat the irons, while with the electric iron practically all of the energy may be utilized.

Various aspects of electric cooking were discussed by Mr. W. L. Waters, as well as economic considerations in connection with industrial applications of heating apparatus and domestic heating by electricity.

Mr. M. C. Turpin spoke of the important central station campaigns and publicity methods for building up the central station heat load.

In closing the discussion, Mr. Swoboda suggested the necessity of manufacturing and offering for sale apparatus of the "hardware type," free of elaborations, suitable for quantity production, simple and substantial in design and requiring minimum cost for operation and maintenance, so that the heating apparatus may be sold by anyone, anywhere. This, he said, will be the secret of the ultimate success of electric heating devices, provided the power supply companies will fix upon some equitable basis for furnishing power at attractive rates to compete more effectively with gas and coal.

Chairman A. M. Dudley presided at the meeting. The total attendance was fifty.

Pittsfield

The second meeting of the Pittsfield Section for the season 1913-1914 was held at the Berkshire Atheneum on October 28. Mr. W. W. Lewis presided, and 130 members and visitors were present. The speaker of the evening was Dr. Ernst J. Berg of Union College, who gave a very interesting talk on the subject of "Lightning." Dr. Berg included in his paper some calculated values of the voltage, current and frequency of lightning strokes, and gave the formulas by which these values can be calculated.

Preceding the meeting a dinner was held at the Wendell Hotel, at which Dr. Berg was the guest of honor.

Portland, Ore.

A joint meeting of the Portland Section A. I. E. E. and the National Electric Light Association was held on October 7, at the Automobile Club, which was attended by 79 members of the two organizations and ten visitors. Mr. E. A. West of the N. E. L. A. presided.

Mr. Griffeth made an informal address on "The Relation of Public Utilities to the Public," and Mr. Davidson gave a talk on "The Objects of the National Electric Light Association."

The next meeting of the two organizations was held at the Royal Arcanum Electric Council Hall at First and Alder

Streets, on November 4. The total attendance was fifty-nine. Chairman G. P. Nock of the Portland Section presided.

The paper of the evening was prepared by Mr. B. C. Condit, chief engineer of the Northwestern Electric Company, and described the plant of his company in Portland. It was read by Mr. R. S. Fisher of the same company. After the reading there was a general discussion.

San Francisco

The October meeting of the San Francisco Section of the Institute was held Friday evening, the 31st, in the Hall of the Native Sons of the Golden West, 430 Mason Street. Chairman A. H. Griswold presided, and 46 members and visitors attended the meeting.

Mr. A. H. Babcock, electrical engineer of the Southern Pacific Company, presented his paper on *Mountain Railway Electrification*, this being the same paper delivered by the author before the Pacific Coast Convention at Vancouver, B.C., in September, and published in the September PROCEEDINGS. Mr. Babcock's paper elicited some very good and active discussion.

Previous to the meeting about twelve members dined informally at Marchand's Restaurant.

Schenectady

The Schenectady Section held the opening meeting of its season on November 5, in the Edison Club Hall, which brought out an attendance of 400 members and 50 visitors. Chairman George H. Hill presided.

The opening address of Dr. E. W. Rice, Jr., marked the formal opening of the Edison Club Lecture Hall, as well as the beginning of the Schenectady Section's season of meetings.

A paper was then presented by Dr. C. P. Steinmetz, on "The Future Development of Electrical Engineering." The subject was further discussed by Messrs. W. L. R. Emmet, E. W. Rice and E. D. Priest.

A smoker was given by the Schenectady Section and the Edison Club in the club's hall on November 8, at which the total attendance was 300. Mr. A. W. Clark, a member of the Section and the club, and chairman of the "get together committee", made the opening address, and then Mr. A. L. Rohrer was called upon and gave a short talk.

Music was furnished by the General Electric Band and by musicians and singers, and the evening of good fellowship was much enjoyed.

Seattle

The Seattle Section held a meeting on October 21, at the Chamber of Commerce. Chairman J. D. Ross presided, and the total attendance was 47.

Mr. R. N. Allen, of the Stone and Webster Engineering Corporation, read a paper on the construction of the 150,000-volt transmission line at Big Creek, California. Mr. Allen had just returned from this work, and gave some interesting and practical notes on the organization and construction work on this big project. A discussion followed, by Messrs. Howe, Harisberger, Miller, Ross, Moore, Terrell, Magnusson and others.

Spokane

The first monthly meeting of the Spokane Section for the year was held following an informal dinner, in the Spokane Club, on October 21, with a total attendance of 43. Owing to the fact that a large number of members reside in the surrounding country, the meeting night was changed from the third Tuesday in the month to the third Friday, so as to permit of the attendance of out-of-town visitors desiring to spend the week-end in town.

Mr. J. B. Fisken, chairman of the Section, who was the delegate of the Section to the Cooperstown convention of the Institute, presented a very interesting report of the convention.

A committee of three was appointed to take up the matter of a hand-book for the Section, which might be of value to all of the members, giving, in concise

form, data of general interest. The committee was also given power to correspond with other Sections with a view to getting any information on similar work which might have been done or might be contemplated by them.

It being the 34th anniversary of the birth of the incandescent lamp, a paper on the history of the incandescent lamp was read by Mr. H. B. Peirce of the commercial department of the Washington Water Power Company.

Toledo

The regular monthly meeting of the Toledo Section was held on November 7, at the Toledo Commerce Club. Chairman George E. Kirk presided, and nineteen were present.

Mr. H. R. Fowler addressed the meeting on "Electric Control of Bridges," with special reference to the Cherry Street bridge. Mr. Fowler described the various types of lift bridges, including the Scherzer, Strauss, Chicago and other patents. The speaker explained the various types of control and signal systems used. Swing bridges were also discussed, and the method of locking them electrically.

A discussion followed, which was participated in by many of those present. A visit to the bridge was made after the meeting, where the equipment was inspected.

Urbana

A meeting of the Urbana Section was held in the electrical engineering laboratory of the University of Illinois, October 15, for the purpose of discussing the policy to be followed for the ensuing year and electing new officers.

The meeting was called to order by Chairman A. M. Buck. The election of the officers was the first order of business, and the following elections were made: Chairman, Professor Morgan Brooks; vice-chairman, Mr. E. S. Scott; secretary, Mr. I. W. Fisk; treasurer, Mr. P. S. Biegler.

After the election of officers Professor Brooks spoke at some length of the policy to be followed for the coming year, mentioning in particular the desire of obtaining outside speakers, and it seemed to be very strongly the sentiment of the meeting that this should be done. Professor Paine also spoke on the affiliation of the Urbana Section of the A. I. E. E. with the Electrical Engineering Society of the University. It seemed that this would be a very effective way of stimulating interest in both organizations. A motion made by Professor Paine, that the executive committee investigate and report on the affiliation of the two societies, was carried. On motion of Professor Buck a committee was appointed to investigate the revision of the by-laws of the Urbana Section and make a formal report at the next meeting.

Professor Buck then made a report on the Cooperstown Convention and the conference of Section delegates, which he attended as the representative of the Urbana Section.

The total attendance at the meeting was fifteen.

Past Branch Meetings

University of Arkansas

A meeting of the University of Arkansas Branch was held on October 21. Chairman S. S. McGill appointed finance and membership committees. A paper on "Elementary Principles of Alternating-Current Signals" was presented by Mr. A. J. Collins, and one on "Signal Repair Work in the Flood District" by Mr. McGill. Mr. J. E. Bell gave an abstract of an Institute paper.

Bucknell University

At the meeting of the Bucknell University Branch on October 15, Mr. Harold Shaeffer gave a talk on "The McCall's Ferry Power House," illustrating his remarks with lantern slides. Professor Rhoades spoke of the origin of the Institute and what it meant to electrical engineers who are members.

University of California

The University of California Branch held a meeting on October 22, when Mr.

F. A. Beik read a paper on "Voltage Regulators."

Three new members were elected at this meeting.

Clemson College

A meeting of the Clemson College Branch was held on October 15. Professor F. T. Dargan spoke on "The Origin and Meaning of the A. I. E. E.," and Professor S. R. Rhoades on "The Technical College Graduate." Reviews of current electrical periodicals were then presented by Messrs. F. H. Robertson, G. R. Morgan and R. S. Hood.

The officers of the Branch for the current session are: Chairman, F. J. Jervey; secretary, F. H. McDonald; treasurer, F. H. Robertson.

Colorado State College

A meeting of the Colorado State College Branch was held on October 19. The election resulted in the unanimous choice of Mr. L. M. Klinefelter as president of the Branch, and Mr. R. K. Havighorst as secretary. After the election the society listened to a talk by Mr. Edgar A. Fuller, a graduate of the electrical engineering department, now in the employ of the Western Electric Company. The speaker devoted himself principally to a description of the Western Electric Company's course for graduates from technical schools. Mr. Fuller then told of his recent work in Denver for the company and some of the problems connected therewith.

University of Colorado

The regular meeting of the University of Colorado Branch was held on October 15. Mr. B. F. Howard of the Mountain States Telephone Company lectured on "The Protection of Lead-Covered Underground Cable Systems from Electrolytic Destruction." Mr. Howard treated his subject from a practical standpoint, and his remarks were illustrated with a number of interesting lantern slides.

At the regular meeting of the Branch held on November 5, Mr. H. C. Parmalee, a prominent electrochemist of Denver, delivered a lecture upon "Electrometallurgy." Mr. Parmalee outlined the various methods of treating ore by electricity, and spoke briefly of the successs and prospects of electrometallurgy in Colorado.

Highland Park College

A meeting of the Highland Park College Branch was held on October 17, at which the speaker was Mr. M. T. McGovern, an alumnus of the electrical engineering department. His talk was upon the test course of the General Electric Company at Schenectady, and the advantages of such a course for young engineers. At the conclusion of his talk Mr. McGovern answered many questions concerning the course.

Iowa State College

The first meeting of the new year for the Iowa State College Branch was held on October 8, when the members heard a lecture by Mr. W. H. Thompson, general manager of the Des Moines Electric Company.

The subject of the lecture was "Modern Methods of Operating Modern Power Plants." Mr. Thompson pointed out all the sources of loss from the coal pile to the switchboard which a manager of such a plant must seek to avoid. He showed the great financial loss which would result if careful supervision is relaxed. The advantage of curve-drawing instruments in maintaining high operating standards was clearly shown. Mr. Thompson also suggested the best methods of handling the boiler and engine room forces in order to secure the desired results without friction. The attendance was 112.

Kentucky University

The Kentucky University Branch held its opening meeting on October 27, with a total attendance of 25. Mr. W. E. Freeman made an introductory address explaining the purposes of the

A. I. E. E. Messrs. R. B. Cottrell and D. M. Gaither, respectively, presented abstracts of two recent Institute papers, *Tungsten Lamps of High Efficiency*, and *Effects of Ice Loading on Transmission Lines*.

Personal

Mr. Robert Lee Baldwin has recently resigned his position as chief of the electrical department of Burns and McDonnell, consulting engineers, of Kansas City, Mo., to become electrical engineer of the Public Service Commission of the State of Missouri, with office in Jefferson City.

Mr. John B. Taylor will shortly enter the consulting engineering field, following 14 years' employment with the General Electric Company, first in the Engineering Department of the Boston District and later at Schenectady in the Railway Engineering Department, as consulting engineer and as engineer of the Foreign Department. Before coming to the General Electric Company he was with the New England Telephone and Telegraph Company. Mr. Taylor will undertake special technical investigations, tests, inspections, etc., and expects to specialize on the relation of the telephone and telegraph to electric light and power systems. He will continue his residence in Schenectady, where he has his own laboratory, and expects to divide his time between that city and New York, with office address to be announced later.

Abstracts of Proceedings of Foreign Engineering Societies

Société Internationale des Electriciens

Meeting of November 5, 1913

" Dynamo-Electric Machines; New Designs: I—Generators with Internal Excitation; II—Synchronous Converters ". By R. V. Picou.

I. *Generators with Internal Excitation.* The limitation of the two constituent parts of a dynamo, the stator and the rotor, to their respective functions of inductor and armature, not being a physical necessity, machines may be conceived in which these functions would be performed by a single one of these two parts. One may conceive a construction in which the same wire will carry both currents, the exciting and the working one. These are internal excitation machines, which the author has studied systematically, and of which he describes certain applications. The paper refers particularly to direct-current generators, where this type appears particularly suitable to generators of large output and to exciters of alternators.

II. *Synchronous Converters.* The author describes a peculiar design of synchronous converters which permits them to start as normal asynchronous motors, and in addition to have a very powerful damping without increase in copper. An investigation of the reaction of the synchronous converter armature shows all the importance of such damping.

" Submarine Telephony ". By M. Devaux-Charbonnel.

Hitherto only comparatively short telephone cables have been placed on the sea bottom, a hundred kilometers at most. It appears that, with our present knowledge of this subject, much longer distances could be successfully handled.

In the first instance it is necessary to investigate how the submarine telephone cable should be made up. It appears necessary to adopt gutta-percha as an insulator, and to have the cable, often immersed at considerable depths, consist of a single conductor. Under these conditions the capacity will be fairly high, and the effective resistance larger than the ohmic resistance. Recent experiments permit us to fix the excess of resistance at 20 per cent. Transformers will have to be installed at the ends of the cable, to connect them with the overland lines, while all reflection losses will be

avoided by properly determining the ratio of transformation.

One may then investigate, by using the processes of artificially increasing the self-induction of Pupin and Krarup, what minimum value will be obtained for the weakening of signals, within practically acceptable conditions of cost and weight. A study of this question shows that, from a theoretical point of view, the Pupin process is preferable. Assuming for the total weakening the value of 2.5, which allows of very good telephonic communication, the distance possible is 600 kilometers with the Pupin system, and 450 with the Krarup system. Local circumstances will have to be considered in deciding which system is to be adopted. In general it appears that the Krarup process is preferable at great depths or in turbulent seas, *i. e.*, wherever the chances of accident are great, and repairs difficult.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

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——Bull. No. 7—Railway, mill, shop, car lighting and auto electrical appliances. May, 1913.
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Madison.........Jan. 8, '09	Edward Bennett.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	Norman Rowe.	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
Milwaukee.......Feb. 11, '10	L. E. Bogen.	A. J. Goedgen, Milwaukee Electric Ry. and Lt. Co., Milwaukee, Wis.
Minnesota.......Apr. 7, '02	W. T. Ryan.	Fred G. Dustin, 9 South Fifth St., Minneapolis, Minn.
Panama.........Oct. 10, '13		
Philadelphia......Feb. 18, '03	A. R. Cheyney.	H. F. Sanville, 1326 Chestnut St., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	A. M. Dudley.	E. R. Spencer, 814 Frick Building, Pittsburgh, Pa.
Pittsfield.........Mar. 25, '04	J. J. Frank.	G. W. Wade, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock,	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
San Francisco.....Dec. 23, '04	A. H. Griswold.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady......Jan. 26, '03	George H. Hill.	John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.
Seattle...........Jan. 19, '04	J. D. Ross.	M. T. Crawford, 608 Electric Bldg., Seattle, Wash.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
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Toronto..........Sept. 30, '03	F. A. Gaby.	H. T. Case, Continental Life Bldg., Toronto, Ont.
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Vancouver.......Aug. 22, '11	E. M. Breed,	L. G. Robinson, 1003 Holden Building, Vancouver, B. C.
Washington, D. C. Apr. 9, '03	H. C. Eddy.	C. B. Mirick, 1302 N Street, N.W., Washington, D. C.

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Arkansas, Univ. of.......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson,	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University......May 17, '10	F. O. Schnure.	J. M. Hillman, Bucknell University, Lewisburg, Pa.
California Univ. of.......Feb. 9, '12	Charles Z. Yost,	L. E. Rushton, University of California, Berkeley, Cal.
Cincinnati, Univ. of......Apr. 10, '08	John H. Stewart.	J. S. Bishop. 2345 Kemper Lane, Cincinnati, Ohio.
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Colorado, Univ. of.......Dec. 16, '04	L. E. Sweitzer.	Frank A. Redding, University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	E. B. Williams.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.......Apr. 15, '03	Earle G. Nicnols.	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of...........May 18, '09	L. F. Hatz.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col....Jan. 10, '08	C. A. Leech.	W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ of.........Mar. 18, '08	S. S. Schooley.	A. J. Fecht, Univ. of Kansas, Lawrence, Kan.
Kentucky, State Univ. of.Oct. 14, '10	H. B. Hedges.	H. Tyler Watts, 315 East Maxwell Street Lexington, Ky
Lafayette College........Apr. 5, '12	G. P. Ellis.	V. A. Davison, Lafayette College, Easton, Pa.
Lehigh University.......Oct. 15, '02	W. B. Todd.	G. Forster, Lehigh University, S. Bethlehem, Pa.
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Michigan Univ of........Mar. 25, '04	P. H. Evans.	W. B. Kopfer, 616 Church Street, Ann Arbor, Mich.
Missouri, Univ of........Jan. 10, '03	H. B. Shaw.	E. W. Kellogg, 9 Engineering Building, Columbia, Mo
Montana State Col.......May 21, '07	Max W. Kenck.	J. A. Thaler, Montana State College, Bozeman, Mont

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Oklahoma, Univ of	Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
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Rose Polytechnic Inst	Nov. 10, '11	Charles F. Harris.	Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.
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Vermont, Univ. of	Nov. 11, '10	Walter L. Upson.	O. Krupp, 65 North Bend St., Burlington, Vt.
Virginia, Univ. of	Feb. 9, '12	Walter S. Rodman	Henry Woodman Clark, A. X. P. House, University, Virginia.
Wash., State Coll of	Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Col of Wash., Pullman, Wash.
Washington Univ	Feb. 26, '04	R. Duncan	C. C. Hardy, Washington University, St. Louis, Mo.
Worcester Poly. Inst	Mar. 25, '04	W. C. Blanchard.	Harry B. Lindsay, Worcester Poly. Inst., Worcester, Mass.
Yale University	Oct. 13, '11	R. G. Warner.	K. B. Jones. 136 Vanderbilt-Scientific, New Haven, Conn.

Total, 47.

ANNUAL CONVENTION, COOPERSTOWN, N. Y., JUNE 23-27, 1913
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ELECTROLYTIC CORROSION OF IRON IN SOILS

BY

BURTON McCOLLUM and K. H. LOGAN

Presented under the auspices of the

Electrochemical Committee

ELECTROLYTIC CORROSION OF IRON IN SOILS

BY BURTON MCCOLLUM AND K. H. LOGAN

Abstract of Paper

The paper deals with the fundamental laws governing electrolytic corrosion of iron in soils. Experimental data are given showing the effect of the different factors that are most likely to influence electrolytic corrosion of buried pipes under practical conditions, such as current density of discharge, moisture content of the soil, presence of oxygen, temperature, voltage, and other factors. The effects of earth resistance, polarization, and surface film resistances are also discussed briefly, and tables are given showing the results of specific resistance and corrosion tests on a large number of soils taken from widely scattered sources, which give an idea of the order of magnitude of the values of resistance and corrosion efficiency that may be expected under average practical conditions.

A number of conclusions are presented showing briefly the effect of the different variables involved and their relation to some practical aspects of the subject of electrolysis.

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 23-27 1913.

ELECTROLYTIC CORROSION OF IRON IN SOILS

BY BURTON MCCOLLUM AND K. H. LOGAN

The term electrolytic corrosion is most frequently used to indicate corrosion caused by the discharge of an electric current which enters the metal from external sources. During recent years, however, the theory has been widely accepted that all corrosion in water solutions is essentially electrolytic in its nature, and in consequence there have come into use a variety of terms such as "galvanic action," "stray current electrolysis." "self corrosion," etc., to distinguish between the cases of corrosion originating from different causes. Thus corrosion of buried iron may be due to galvanic action caused by physical or chemical differences between adjacent points on the surface of the metal, to the presence of foreign substances in the soil such as coke, cinders, iron oxides, etc., which set up local galvanic action, or it may be due to the discharge of electric currents that have entered the structure at some remote point. In the present paper the terms "electrolysis" and "electrolytic corrosion" are used to designate corrosion caused by the discharge of electric current which has entered the metal from some outside source, while all other forms of corrosion in which the electric currents originate within the corroding system itself from whatever cause, are referred to as "self corrosion." It should be pointed out at the outset, however, that these two general classes of corrosion are by no means independent of each other, since the presence of either kind of corrosion, generally affects in marked degree the nature and extent of the other under a given set of conditions. This mutual influence is such as to be of considerable practical importance, and in particular it often greatly increases the difficulty of obtaining

trustworthy experimental data in regard to electrolytic corrosion proper.

The data herein presented represent a portion of the work done by the Bureau of Standards in connection with a more general investigation of the subject of electrolysis and electrolysis mitigation which has been in progress for some time past. The present paper is designed to deal only with the fundamental laws governing electrolytic corrosion under practical conditions, and relates to self corrosion only in so far as it is necessary to distinguish between the two classes. The subject of the prevention of electrolytic damage is referred to only incidentally when occasion requires in order to interpret the significance of results obtained. This matter of electrolysis has been given much attention, but is far too comprehensive a subject to be dealt with in a brief paper such as can be presented here. It will be treated at some length, however, in a report which will be issued shortly by the Bureau of Standards dealing exclusively with the subject of electrolysis mitigation.

In studying the phenomena of electrolytic corrosion in soils under practical conditions many variables are encountered which tend in greater or less degree, to affect the results. Among these may be mentioned the current density at the surface of the metal, the moisture content of the soil, and the presence of oxygen either in the gaseous state or dissolved in soil waters. The latter not only affects the rate of corrosion but also affects the character of the end products of the reactions and thus to some extent has a bearing on the question of diagnosing the cause of particular cases of corrosion. The temperature of the soil is also important, particularly because of its effect on the current flow. In the case of iron, the formation of oxides as a result of the initial corrosion may complicate matters because of their possible effect in stimulating galvanic action. Other factors, such as the mechanical and chemical properties of the soil, the depth of burial of the metal, the limitation of current flow due to polarization, the formation of high resistance films on the surface of the metal, and the pitting of the surface due to a variety of causes may likewise act to increase or decrease the rate at which damage may progress, and therefore require special investigation. Finally, since it is not practicable to carry on all experiments in the field under practical conditions it is necessary to study the possible differences in results that may in some cases occur between experiments performed in

the laboratory and in the field. It is these factors that are dealt with in the following pages, and while the investigations have in most cases not yet been completed, we believe that the data thus far obtained will be of sufficient interest to justify a report of progress at this time.

While the corrosion of iron by electric currents may be influenced by a variety of causes, nevertheless the data to be presented later show that under most practical conditions the extent of the corrosion is largely a function of the quantity of electricity that is discharged from a given surface. This is a quantity that can be readily measured under laboratory conditions and we have therefore determined, in all cases, the corrosion as a function of the ampere-hour discharge from the anode. The results are expressed in terms of the "corrosion efficiency." If the corrosion of the anode is the sole action involved at the anode then according to Faraday's Law 96,540 coulombs are required to corrode one gram-equivalent of the metal and the corrosion efficiency is said to be 100 per cent. In most cases, however, the actual corrosion noted is either greater or less than this amount and the percentage which the actual corrosion in any case, is of the theoretical amount is called the "efficiency of corrosion" under those conditions. The experimental data presented in the first part of this paper show how the efficiency of corrosion is affected by the varying physical conditions encountered in practise. The corrosion efficiencies are in all cases calculated on the assumption that the iron is divalent. The experiments presented show that in most cases at least this is true, since as a rule, the corrosion efficiencies observed have been near or above one hundred per cent. This is therefore the logical basis on which to figure the efficiency of corrosion. In those cases where the corrosion efficiency was very low it may be due in part to the iron taking the ferric state, and such tendency, when it exists may therefore be regarded as one of a number of possible causes of low efficiency of corrosion. The various factors enumerated above which affect the efficiency of corrosion of iron in soils are discussed in detail in a later part of this paper.

Arrangement of Apparatus

The methods of conducting the experiments recorded below were in general the same, and may, therefore, be described once for all.

The local earths used in the laboratory tests were from virgin soil near the laboratory, sifted to remove stones and to insure uniformity. This earth was mixed with the desired amount of distilled water and placed in tin cans which served as cathodes. The bottoms of the cans were separated from the earth by a thick layer of paraffin or other insulating material so that the discharge from the anode placed in the center of the can would be substantially uniform and only toward the sides of the can. The outsides of the cans were insulated from each other by several layers of heavy paraffined paper. In a number of experiments, however, the test specimens were buried in virgin soil out of doors in order to compare directly the corrosion found under these conditions with the corrosion which resulted when the tests were made in the laboratory.

Cleaning of Anodes

In cleaning the anodes and determining their losses, a number of precautions are necessary. It has been shown that many solutions render iron at least temporarily passive. Such solutions are, of course, not desirable for cleaning iron previous to a test. The iron used was filed and sandpapered to remove dirt and scale, cut into suitable lengths, stamped on one end for identification with steel numbers, and weighed. Rubber covered leads were then soldered to the unnumbered ends of the anodes and both ends covered with paraffin or pitch. To make these stick to the iron it is necessary that it should be rather hot when they are applied. The specimens were then thoroughly washed with gasoline to remove any grease due to handling and finally dried with a towel. At the close of the experiment the specimens were washed and brushed to remove all loose dirt and then made cathode in a two per cent solution of sulphuric acid with a high current density. To prevent plating a non-corrodable anode should be used. This method of cleaning was developed after various mechanical and chemical methods had been tried with inconsistent results and has proven very satisfactory. The specimens came from the solution perfectly clean within ten to thirty minutes and careful tests have shown that clean iron subjected to the treatment suffers no loss.* The method seems very much preferable to any mechanical method we have tried, since when the rust sticks very tightly or the iron is rough, it is impossible to remove the

*This does not apply to cast iron.

corrosion products without scraping off some of the iron with them. In a few instances where it was not convenient to clean the iron electrolytically, as in the case of hollow anodes too small to permit the interior to be protected by inserting an anode, a solution of ammonium citrate has been used. This latter method is satisfactory except in the case of deep pits, especially if a warm solution is used.

The paraffin protecting the ends of the specimens was removed by gasoline and the pitch by toluol. The solder attaching the leads was melted and carefully wiped off. We have also tried dissolving the solder by mercury but the process is slow unless heat is used, and the result no better than the easier method.

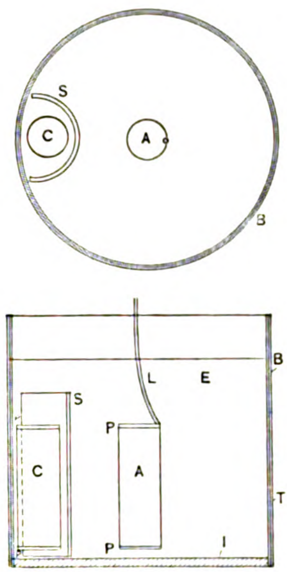

Fig. 1.—Arrangement of Anode and Check Specimen

A—Anode $1\frac{1}{2}$ in. diam., B—paraffined paper, 2 layers; C—check specimen $1\frac{1}{2}$ in. by $\frac{1}{2}$in. diam., E—earth, I—paraffine $\frac{1}{8}$ in., L—lead No. 18 rubber covered. P—pitch layer, S—glass shield one inch diam., T—tin can 3 in. diam. $3\frac{1}{4}$ in. high.

Check Specimens

Correction for the loss by the anodes due to self corrosion was made by placing a check specimen inside each can and screening it from the anode by a shield of glass or paraffined paper. Fig. 1 shows the arrangement of the anode and check specimen. The loss of the check specimen has been deducted from the loss of the anode and the difference used as the loss due to electrolysis. It will be shown later that the loss of check specimen in a can with an anode is considerably greater than that of a similar check specimen in a separate vessel of the same earth and it seems therefore that part of the loss in the former case is due to some effect of the current and should be against it. The corrosion efficiencies found are therefore charged lower than if check specimens in separate cans were used. However, there are several advantages in keeping the check specimen in the can with the anode and the increased loss on this account is usually small compared with the total loss of the anode.

Determination of Ampere Hours

To obtain the corrosion efficiency it is, of course, necessary not only to determine accurately the loss of the anode, but equally essential to know the quantity of electricity discharged by it. To obtain this, the specimens were so arranged that the currents could be read at frequent intervals, compensation being provided where necessary for the resistance of the milliammeter. Curves were plotted showing the relation between current and time and the area between the curve and the axes determined with a planimeter. While the exact current values between times of observation are unknown, the areas represent a value of the ampere-hours sufficiently accurate for practical purposes, and the large number of circuits operating at one time made the use of more accurate recording instruments out of the question.

I. FACTORS AFFECTING EFFICIENCY OF CORROSION

1 *Effect of Current Density.* A number of investigators have reported experiments showing that the amount of corrosion which results from a given ampere-hour discharge varies greatly from the theoretical amount. Among these may be mentioned the work of Hayden[1] and of W. W. Haldane Gee [2] who worked with high current densities, and observed that there was a marked tendency for the iron to become passive, the resulting corrosion being considerably less than the theoretical amount. In general this tendency toward passivity was much more marked when the current density was made very high. These experiments were carried out with test specimens immersed in liquid baths, however, so that the conditions were very different from those which prevail in ordinary street soils. Ganz[3] has reported the results of experiments carried out in certain soils, which showed that the actual corrosion observed was much greater than the theoretical amount, in some cases the loss in weight being as much as several times the loss calculated from Faraday's law. In these experiments very low current densities were used and the earth contained considerable quantities of salt and this may have affected the result. The authors have carried out several series of experiments in which the aim

1. *Journal of the Franklin Institute*, Vol. CLXXII, p. 295.
2. *Journal of the Municipal School of Technology*, Manchester, Vol. 2, 1910.
3. PROCEEDING A. I. E. E. June 1912, pp. 1001—1010.

has been to maintain conditions as nearly as possible approximating those which will be encountered in practice, both as regards soil conditions, and current densities. The soil used was a virgin soil taken from a sparsely settled portion of the residential district of Washington. An analysis was made of a typical sample of the soil for those ingredients which are most likely to affect corrosion, the results being shown at the top of Table I along with the data on efficiency of corrosion. In determining the current densities to be used values were chosen of such magnitude as could give rise to considerable injury within a period varying from a few months of fifteen or twenty years. For example, the highest value used was about 5 milliamperes per square centimeter, which under uniform distributio n and at 100 per cent efficiency of corrosion would cause the corrosion to progress inward at the rate of about 5.7 centimeters per year, which corresponds to a rate rarely exceeded under practical conditions. The minimum current density used was 0.05 milliamperes per square centimeter which corresponds to a normal rate of corrosion of about one centimeter in 17 years. These extreme ranges represent therefore the limits between which the corrosion is of much practical importance.

Several series of experiments were made, the data presented in Tables I and IA being typical of the series. The corrosion efficiencies under table I are for a soil containing considerably less moisture than those under Table IA, which are obtained on a soil practically saturated with water. In the former the test specimens were all imbedded in samples of earth placed in tin cans as described above, while in the second series half of the tests were run with specimens buried to a depth of about 2½ ft. (76 cm.) in the ground out of doors.

The data in Table I are plotted in Fig. 2, and those of Table IA are plotted in Figs. 3 and 4, the curve of Fig. 4 being a continuation of that of Fig. 3, but on a smaller scale. While the points do not lie on a smooth curve, because of a number of disturbing factors to be discussed later, the trend of the curves is nevertheless unmistakable. They show corrosion efficiencies varying greatly with the current density, the ranges being from about 20 to 140 per cent for the range of current density varying from about 5 to 0.05 milliamperes per square centimeter, the lower corrosion efficiencies being obtained at the higher current densities. All of the data in Tables I and IA are plotted as a single curve in Fig. 5, which in spite of

TABLE I

RELATION BETWEEN CURRENT DENSITY AND EFFICIENCY OF CORROSION

PARTIAL ANALYSIS OF SOIL USED IN TESTS

Cl_1	NO_3	CO_3	SO_4
0.002%	0.002%	0.003%	0.004%

No.	Current Density mil. amps. per sq. cm.	Efficiency of corrosion
1	2.0	57.0
2	1.8	37.4
3	1.7	69.2
4	1.6	43.2
5	1.5	84.3
6	1.3	75.8
7	1.2	72.8
8	1.1	83.8
9	1.0	89.2
10	0.8	75.0
11	0.7	88.3
12	0.6	79.1
13	0.5	75.2
14	0.4	102.1
15	0.3	142.2
16	0.2	96.2
17	0.1	148.4
18	0.05	142.9

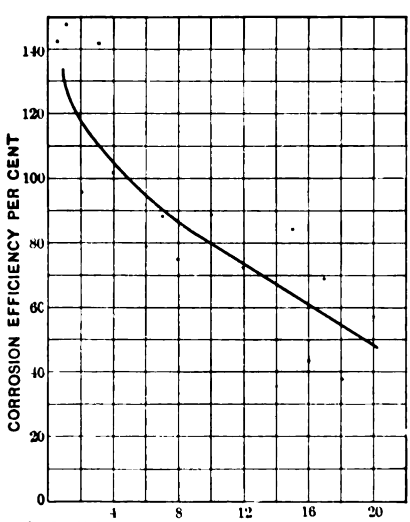

FIG 2.—CORROSION EFFICIENCY—CURRENT DENSITY

the irregularities in the individual points shows clearly the decided falling off in efficiency of corrosion with increase in current density. It is interesting to note here that the points in Fig. 5 marked with an X were taken out of doors in native earth while those marked with dots and circles were two separate

TABLE I-A

CURRENT DENSITY-CORROSION EFFICIENCY

AREA OF ANODES, 70.9 SQ. CM. TIME OF RUN, 115 HOURS

No.	Current density mil. amps. per sq. cm.	Corrosion efficiency
19	0.034	124.1
20	0.064	115.0
21	0.088	141.5
22	0.129	123.6
23	0.150	104.6
24	0.163	118.3
25	0.206	125.8
26	0.222	117.1
27	0.258	101.8
28	0.279	113.4

CURRENT DENSITY CORROSION EFFICIENCY

72-HOUR RUN IN SATURATED SOIL IN LABORATORY. 4-27-13 TO 4-30-13. EXPOSED ANODE AREA, 11.78 SQ. CM.

No.	Current density Mil. amps. per sq. cm.	Corrosion efficiency
29	0.48	102.5
30	1.01	98.1
31	1.26	78.3
32	1.84	102.2
33	2.28	63.6
34	2.50	78.1
35	3.45	52.9
36	4.27	43.6
37	4.29	27.4
38	4.72	20.4

series taken indoors using small samples of earth in cans. The agreement between the different groups is fully as good as that between different points of the same group, which indicates that the results obtained on small samples in the laboratory are substantially the same as those obtained on specimens

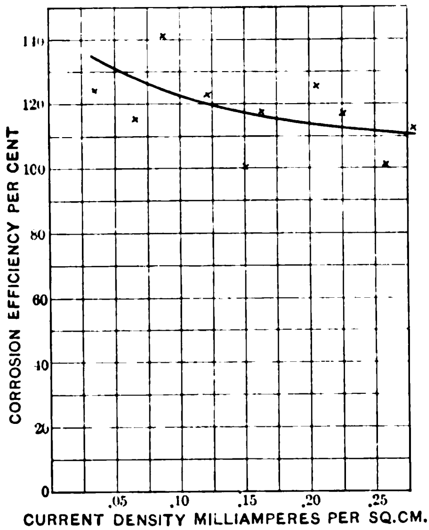

FIG. 3.—CORROSION EFFICIENCY—CURRENT DENSITY

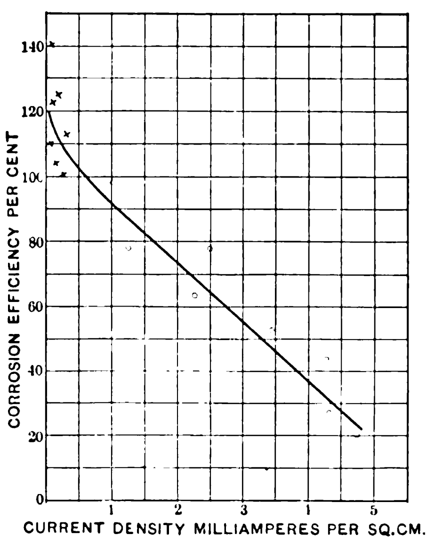

FIG. 4.—CORROSION EFFICIENCY—CURRENT DENSITY

buried in the earth out of doors. This gradual change in corrosion efficiency with current density does not appear in accord with the results of Hayden, Haldane Gee, and others, whose work with liquid electrolytes seemed to indicate an abrupt change in efficiency of corrosion from 100 per cent to zero at a critical current density.

It will be noted that these results do not show as high efficiencies of corrosion as those reported by Prof. Ganz[4] who found values ranging over 500 per cent. It should be noted, however, that the results obtained by Prof. Ganz were for the most part obtained on much lower current densities than were used in the present experiments. It is seen also from Fig. 5 that as the lower current densities are approached the curve tends rather strongly upward, indicating that if the current density

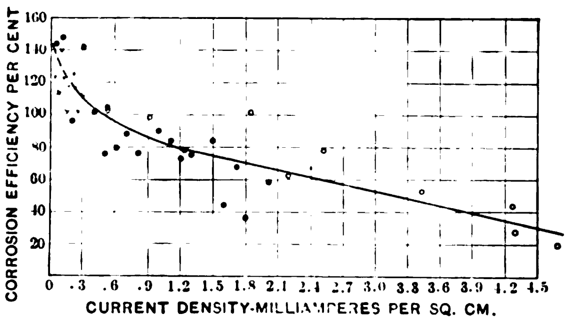

FIG. 5.—CORROSION—CURRENT DENSITY

had been reduced to the low value used by Ganz, the corrosion efficiencies might have reached the high values found by him. As pointed out above, however, lower current densities than those used in the present series, although of great theoretical interest, are of little consequence from the practical standpoint.

2 *Effect of Moisture on the Rate of Corrosion.* The following experiment was tried to determine whether the amount of moisture in the soil affected the corrosion efficiency of iron buried in it:

A quantity of red clay soil was air dried and then distilled water was added, a can of earth taken out; more water added, etc., till twelve cans of earth had been obtained.

The ends of the specimens and the bottom and outside of the cans were insulated as in previous tests, and small dishes

4. Ganz, PROCEEDINGS A. I. E. E., June, 1912.

of water placed inside the can to retard evaporation. The six cans were connected in series, the sides of the cans serving as cathodes and a current of two milliamperes giving about one milliampere per square centimeter was maintained by daily adjustments for 86 days. At the end of this time the resistance had increased so much that it was difficult to maintain the current and the specimens were, therefore removed, cleaned and weighed. The efficiency of corrosion was then computed, corrections being made for self corrosion.

While the current was flowing, samples of the earth taken when the specimens were placed in the cans, were dried for about a week in an oven at a temperature of 105 deg. cent. and the percentage of moisture computed from the loss of weight. The

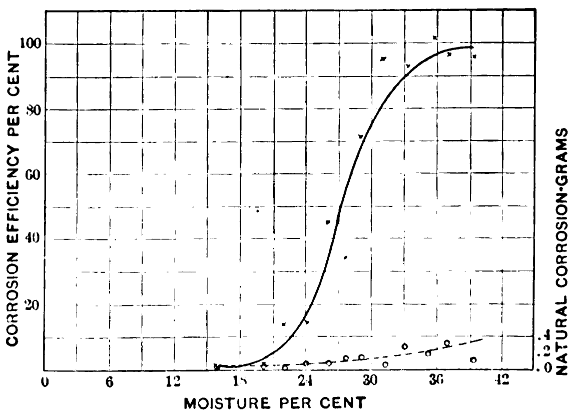

FIG. 6.—CORROSION EFFICIENCY MOISTURE
Natural corrosion moisture

per cent of moisture is expressed in terms of the earth before drying.

The result of this test is given in Table II, and plotted in Fig. 6.

Looking at the curves of self and electrolytic corrosion, it will be seen that where a point on one curve is too high, the corresponding point on the other curve is too low. Since the electrolytic curve was obtained after natural losses had been deducted it is evident that part of the irregularities is due to incorrect values of the natural loss. However, the natural loss is so small that in most cases it could not account for the entire variation in the electrolytic curve. Since all wrought iron contains more or less slag it is probable that the presence

of minute slag particles explains, in part at least, the pitting and variations of results from expected values.

The results of these tests show that the corrosion efficiency varies greatly with the moisture content of the soil, being so small as to be practically negligible when the soil is fairly dry, but approaching values of the order of 100 per cent when the soil becomes saturated. In these tests there was very little corrosion when the moisture content was below 20 per cent It should not be assumed however, that the numerical values given here will hold for all soils, since there is considerable uncertainty as to the conditions which actually prevail.

In the first place the percentage of moisture required to produce a wet condition of the soil varies greatly with different

TABLE II
EFFECT OF MOISTURE ON CORROSION

No.	Per cent moisture	Loss—grams			Per cent Efficiency
		Total	Natural	Electrical	corrosion
1	15.9	0.090	0.044	0.046	1.1
2	20.0	0.110	0.040	0.070	1.6
3	22.5	0.623	0.039	0.584	13.7
4	23.8	0.715	0.080	0.635	14.9
5	26.0	2.002	0.073	1.929	45.3
6	27.6	1.579	0.145	1.434	33.7
7	28.9	3.192	0.160	3.032	71.2
8	31.1	4.182	0.121	4.061	95.4
9	33.3	4.217	0.265	3.952	92.8
10	35.7	4.545	0.207	4.338	101.9
11	37.0	4.463	0.335	4.132	97.0
12	39.4	4.218	0.125	4.093	96.2

soils so that the percentage of moisture cannot be taken as a measure of the condition of dryness. In the red clay soil used in these tests the soil appeared to be barely moist at 15 or 20 per cent moisture; whereas in many cases we have since encountered numerous soils in which 10 per cent of moisture caused it to appear quite wet. There may also be variations due to differences in soil composition which affect the efficiency of corrosion. Further, while the average current density in these experiments was maintained practically constant it is not improbable that the actual current density varied considerably. When the soil was practically saturated with water the current density would probably be nearly uniform, but as the moisture content is reduced and some of the pores in the soil became voids,

there would be a tendency for the current to discharge locally at the points of contact between earth and iron, and it appears possible that this might give rise to great variation in the actual current density of the discharge. It has already been seen that at high current densities the efficiencies of corrosion tend to become smaller, so that the variations in efficiency of corrosion here observed as due to changes in moisture content, may after all be due in large part to changes in current density. However, this may be, the important fact is that the amount of corrosion per ampere-hour is likely to be quite low in the case of fairly dry soils while as the percentage of moisture approaches that corresponding to saturation the corrosion efficiency approaches 100 per cent for the particular value of current density used in this series, namely, one milliampere per square centimeter.

3 *Effects of Temperature.* In order to study the effects of temperature on the efficiency of corrosion of iron in soil, three series of experiments were carried out. In the first of these, the temperature of the cans containing the earth samples was maintained practically constant at between zero and one deg. cent. by means of an ice bath; the second was run at between 24 and 27 deg. cent., which corresponds to about average summer temperature in soils, and the third group was maintained at between 35 and 40 deg. cent. by means of an automatically regulated oven. Four specimens were used in each group, and the current density was maintained practically constant at about 0.84 milliamperes per square centimeter.

The tests were all run in the same kind of earth, which was kept practically saturated with moisture. The results of these tests are given in Table III. An examination of the values of efficiency of corrosion will show that they are practically independent of the temperature. It appears therefore, that it is safe to assume that throughout the range of temperatures that is likely to be encountered under practical conditions, temperature variations have no marked effect on the corrosion efficiency of iron in soils. This does not mean, however, that temperature is not an important factor in electrolysis under practical conditions, for the reverse is true; but this grows out of the effect of temperature on the resistance of the soil rather than on the efficiency of corrosion. It is shown in a later part of this paper that the resistance of soils varies with temperature in a very remarkable manner even within the ranges of temperature that

are likely to occur in soils under ordinary conditions, and that the effect of this change in resistance on the current flow is such as to make the actual amount of electrolysis which may be expected, vary greatly with temperature. This matter is discussed later under the head of earth resistance.

4 *Effect of Depth of Burial on Efficiency of Corrosion.* Inasmuch as the efficiency of corrosion is found to vary greatly under different conditions it was deemed advisable to investigate whether the depth to which a pipe is buried below the surface would have any effect on the efficiency of corrosion. Accordingly a number of specimens were prepared and buried in earth

TABLE III

EFFECT OF TEMPERATURE ON CORROSION EFFICIENCY

No.	Temperature	Corrosion efficiency
	deg. cent.	
1	35 to 40	98.2
2		103.4
3		97.0
4		98.4
	Average	99.2
5	24 to 27	98.2
6		97.6
7		97.9
8		97.6
	Average	97.8
9	0 to 1	93.8
10		95.7
11		99.1
	Average	96.2

Average current density 0.84 milliamperes per sq. cm.

to distances varying from a few inches to about six feet. A check specimen was provided in each case to permit correction for self corrosion, and it was so shielded as to prevent the passage of any current through it. The anodes and check specimens alternated with each other in the order given in Table IV. In correcting for self corrosion the mean of the losses on the check specimens on both sides of each anode was used. The specimens were buried in virgin red clay soil and were run at an average current density of about 0.056 milliamperes per sq. cm. for about 1490 hours. The results of the tests are shown in Table IV and plotted in Fig. 7., which gives curves of both self corrosion and efficiency of corrosion as a function of depth. It will

be seen that the results, while somewhat irregular, indicate that there is but slight variation attributable to depth, although there seems to be a trend upward in the case of self corrosion. The variation in efficiency of corrosion with depth is probably due to the fact that the moisture content varied with depth. The fact that no greater variation was observed is doubtless due to the fact that the tests were carried out at a time when the soil was fairly wet both near the surface and at greater depths. The results given above on the effect of moisture content indicate that if the experiments had been made in a fairly dry time when there was considerable variation of moisture content with depth, the corrosion efficiency would probably have shown a

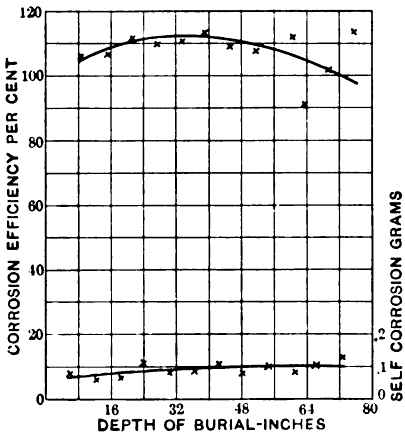

FIG. 7.—CORROSION EFFICIENCY—DEPTH

corresponding variation. When conditions are such that there are considerable variations in moisture content with depth as in a moderately dry time for instance, the preceding data indicate that the efficiency of corrosion would probably also vary greatly with depth, being in general, greater the greater the depth.

Effects of Oxygen on Corrosion of Iron. Since, according to the electrolytic theory of corrosion, the presence of oxygen is an essential factor in the production of self corrosion of iron in the presence of water, it might be expected that the electrolytic corrosion of iron by stray currents would be affected in a marked degree by the content of dissolved oxygen in soil water. In order to investigate this point ten anodes and a corresponding number of check specimens having an exposed area of 90 sq.

cm. each were prepared in the usual way and connected in series and run on a practically constant current density of 0.056 milliamperes per square centimeter. Five of these jars were so arranged that oxygen bubbled through the liquid continuously throughout the entire experiment, and the other five were immersed in the water without oxygen being

TABLE IV

EFFECT OF DEPTH OF BURIAL ON NATURAL AND ELECTROLYTIC CORROSION

WROUGHT IRON CYLINDERS 2 IN (5.08 CM.) LONG AND 1⅜ IN. (3.4 CM.) IN DIAMETER POLISHED. ODD NUMBERS CARRIED CURRENT. EVEN NUMBERS ARE FOR NATURAL CORROSION

No.	Total loss	Electrical Loss	Loss theoretical	Per cent efficiency	Depth
					Inches
1	9.260 g.	7.972 g.	6.990 g.	114	75
2	1.288				72
3	9.475	8.319	8.119	102	69
4	1.024				66
5	7.630	5.685	6.280	91	63
6	0.875				60
7	10.862	9.929	8.785	113	57
8	0.991				54
9	9.422	8.512	7.890	108	51
10	0.829				48
11	8.505	7.503	6.959	109	45
12	0.995				42
13	8.822	7.866	6.942	113	39
14	0.916				36
15	8.225	7.341	6.618	111	33
16	0.852				30
17	6.899	5.913	5.385	110	27
18	1.120				24
19	7.331	6.424	5.780	111	21
20	0.694				18
21	4.667	3.993	3.732	107	15
22	0.654				12
23	5.092	4.420	4.226	105	9
24	0.690				6

Area of surface 70.9 sq. cm.
Mean current density about 0.059 milliamperes per sq. cm.

passed through them. At the end of 183 hours the experiment was completed and the anodes were weighed and efficiencies of corrosion calculated. The data are given in Table V from which it will be seen that there is considerable variation in the efficiencies of corrosion for the individual specimens. These variations are so large that the difference between the average of the five specimens in the jars through which oxygen was

passed (98.5 per cent), and the average for those specimens in the remaining jars (91 per cent) has but little significance. It is, of course, necessary to bear in mind in interpreting these results that even the water through which oxygen was not passed, contained a good deal of oxygen in solution, so that any differences in efficiency of corrosion that might be indicated would be those due to a somewhat indefinite difference in the oxygen contained in the water.

TABLE V

EFFECT OF OXYGEN ON EFFICIENCY OF CORROSION

CURRENT DENSITY 0.056 MILLIAMPERES PER SQ. CM. TIME 183 HR. AREA OF ANODES 90 SQ. CM.

A—OXYGEN ADDED

No.	Total loss	Self corrosion	Electrical loss	Per cent Efficiency of corrosion
0	1.248g.	0.182g.	1.066g.	110.7
1	1.251	0.312	0.939	97.5
2	1.296	0.330	0.966	100.5
3[1]	0.993	0.067	0.929	96.5
4	1.128	0.327	0.801	87.0
			Average	98.5

B—NO OXYGEN ADDED

No.	Total loss	Self corrosion	Electrical loss	Per cent Efficiency of corrosion
5[1]	0.886	0.030	0.873	90.6
6	0.940	0.027	0.913	94.9
7	0.913	0.029	0.884	91.7
8	0.889	0.030	0.859	89.0
9	0.895	0.040	0.855	88.7
			Average	91.0

1. Buried in sand.

In order to check this result more carefully two series of experiments were carried out in which a much larger difference in the oxygen content in the two cases was maintained. In each series four specimens were used, two being placed in tap water and the other two in a 10 per cent solution of sodium sulphate. In one series the liquids were first boiled down to half their original volume in Erlenmeyer flasks to remove oxygen and the iron electrodes inserted during boiling. After the boiling, an atmosphere of hydrogen was introduced into

the flasks as they cooled down, so that practically no oxygen could have access to the liquid. In the other series air was caused to bubble through the liquid throughout the experiment so that an abundant supply of oxygen was always present. The results are given in Table VA. From this table it will be seen that there is no appreciable difference between the efficiencies of corrosion in the presence of oxygen and in the absence of oxygen at least in the liquid electrolytes here used. We have reason to believe however, that this is not the case when the anodes are buried in soils, although just why a difference should

TABLE VA

EFFECT OF OXYGEN ON EFFICIENCY OF CORROSION

No.	Solution	Weights: Original	Weights: Final	Loss	Per cent Corrosion efficiency
		Without Oxygen			
1	H_2O	51.326g.	50.624g.	0.702g.	96.2
2	H_2O	51.570	50.871	0.699	95.8
3	10% Na_2SO_4	52.361	51.651	0.710	97.3
4	10% Na_2SO_4	51.642	50.935	0.707	96.9
				Average	96.5
		With Oxygen			
5	H_2O	51.852	51.154	0.698	95.7
6	H_2O	52.725	52.044	0.681	94.7
7	10% Na_2SO_4	51.467	50.759	0.708	97.0
8	10% Na_2SO_4	51.034	50.317	0.717	98.2
				Average	96.4

Theoretical loss, 0.730 g.
Area of anodes, 15.2 sq. cm.
Current density, 1.45 milliamperes per sq. cm.

exist here is not clear. That there is a difference is borne out by a number of tests we have made with anodes buried in earth in hermetically sealed cans and others buried in cans exposed to the atmosphere, conditions as to moisture content, current density, etc. remaining the same. Whenever the tests were continued for a considerable time it was found that the efficiency of corrosion in the sealed receptacle was in nearly all cases considerably lower than when the container remained open. This effect is shown in Table VI.

The average corrosion efficiency in the closed cans was 85.5 per cent while that in the open cans was 105.7 per cent.

Whether or not this difference is due to the difference in the amount of oxygen or CO_2 present or to other causes, it affords another indication of the danger of drawing conclusions from experiments made in liquid electrolytes as to what would occur in the case of electrodes buried in soils.

6. *Effect of Oxygen on the End Products of Corrosion.* One very marked effect of oxygen on corrosion however, is its influence on the final products of electrolysis. There is a very common impression extant that the final products of corrosion of iron due to stray currents are the black oxides, whereas in the case of self corrosion red oxides are produced. This is not in

TABLE VI

CORROSION EFFICIENCIES IN OPEN AND CLOSED CANS

No.	Efficiency of corrosion	
	Closed cans	Open cans
1	87.9	
2	77.4	
3	95.2	
4	79.9	
5	95.4	
6	77.2	
7	85.8	
8		106.5
9		105.5
10		105.3
11		105.5
Average	85.5	105.7

Average current density, 0.494 milliampere per sq. cm.
Area of anodes, 9.4 sq. cm.

accord with accepted theories of corrosive processes, and the following experiments have been carried out in order to demonstrate that in general this is not the case, although under certain circumstances the tendency may be in that direction.

Four tests were made in which ingot iron was allowed to corrode naturally in the absence of oxygen, one test being in distilled water, two in tap water, and one in 10 per cent $Na_2 SO_4$ solution. Four tests were made in which the iron was allowed to corrode naturally in the presence of oxygen, two tests being in distilled water and two in tap water. Four tests were made in which the iron was allowed to corrode electrolytically in the absence of oxygen, the electrolyte being tap water in two of the tests and 10 per

cent Na_2SO_4 solution in the other two. Four tests were also made in which the iron was allowed to corrode electrolytically in the presence of oxygen, two tests being in tap water, and two tests in 10 per cent Na_2SO_4 solution.

The solutions were prepared practically free from oxygen by boiling down to about half their original volume in Erlenmeyer flasks. The iron test pieces were introduced during the boiling, and after the boiling was stopped the flasks were closed off from the air and a current of hydrogen free from oxygen was allowed to pass into the flasks as they cooled down, thus keeping the solutions under an atmosphere of hydrogen.

In the case of the natural corrosion tests in the absence of oxygen, the iron showed no corrosion at first, but after a day or two a few spots of greenish-black rust were noted, which gradually became larger as time went on, with the formation of a small amount of yellow ferric oxide. This was probably due to the fact that the air gradually diffused in through the rubber connections. In the case of the natural corrosion tests in the presence of oxygen, the rust was soon apparent and consisted almost entirely of the yellow ferric oxide. Thus we see that when oxygen is almost entirely excluded, the ferrous oxide predominates, and when oxygen is present, the ferric oxide predominates.

In the case of the electrolytic corrosion tests, the eight flasks were connected up in series, and a current of about 0.025 amperes allowed to pass for about 27 hours. At the end of this time the current was stopped and the anodes were taken out and weighed and the loss in weight determined. It was found that the corrosion efficiency was practically 100 per cent in all cases, calculating with iron having a valence of two. In the case of the four flasks from which air was excluded, the iron was practically all in the ferrous condition, the corrosion products having the pale green color of the hydrated ferrous oxide. Analysis of the corrosion products in one of the flasks gave 98.9 per cent ferrous iron, the slight oxidation being probably due to the unavoidable introduction of air into the flask during the removal of the electrodes for weighing. Through two of the other four flasks a current of air was allowed to bubble during the course of the electrolysis, and in those two flasks the corrosion products had the reddish yellow color of the hydrated ferric oxide, showing that the iron was largely oxidized to the ferric condition. The other two flasks were left open to the air, but air was not bubbled

through, and in these flasks the corrosion products had a darker color and when filtered off, dried, and tested with a magnet showed the presence of considerable magnetic oxide. Evidently then the corrosion had proceeded so fast that there was not enough oxygen present to oxidize the oxide completely to the ferric condition, but in the other case where air was bubbled through the solution, the solution was kept saturated with oxygen and so the oxide was converted completely to the ferric condition.

These results show that when iron corrodes electrolytically, it corrodes as the ferrous oxide and that the formation of higher oxides is due to the oxidation of the ferrous oxide by the oxygen of the air, the degree of oxidation depending on the rate of corrosion and the concentration of the oxygen. If the rate of corrosion is relatively rapid and the concentration of the oxygen is relatively low, there will be a predominance of the lower oxides, *i.e.*, the ferrous oxide and the magnetic oxide; on the other hand, if the reverse is the case, *i.e.*, if the rate of corrosion is relatively low, there will be a predominance of the ferric oxide.

The same explanation will apply to natural corrosion. In this case the rate of corrosion is very slow and so the ferric oxide predominates; and even when the oxygen is almost entirely excluded, the rate of corrosion is so slow that there is a slight formation of ferric oxide, although the ferrous oxide predominates.

From the foregoing it will apear that the character of the end products of corrosion does not depend essentially on the cause of the corrosion, but that either of the oxides may be produced, both in the case of self corrosion, and in the case of electrolytic corrosion. It may, however, throw some light on the question in many circumstances for the reason that the rate of natural corrosion of pipes imbedded in earth may usually be expected to be so low that practically nothing but the ferric oxides would be produced, there being enough oxygen in the soil waters to oxidize any ferrous iron that may be formed. In the case of electrolytic corrosion, however, this will not always be the result, the corrosion being so rapid, especially under bad electrolysis conditions that the supply of oxygen in the ground waters will not be sufficient to oxidize all of the ferrous iron, and the result will be the formation of a considerable amount of magnetic oxide. This, however, will no doubt be largely affected by the depths of the pipe below the surface. The deeper the pipes,

as a rule, the less would be the available supply of oxygen, and the greater would be the tendency for the formation of the magnetic oxide. Pipes very close to the surface even though corroding very rapidly by stray currents might still form little if any magnetic oxide, because of the abundant supply of oxygen that would be available. Nevertheless, wherever a large preponderance of magnetic oxide exists, while it does not definitely prove that the corrosion has been due to stray currents, it may usually be regarded as a good indication that the rate of corrosion has been so great as to make it altogether probable that stray currents have been largely responsible, unless soil conditions, such as the presence of cinders, coke, chemicals, etc., are such that extremely rapid self corrosion may be indicated.

7 *Relative Electrolysis in Different Kinds of Iron.* The question as to relative tendencies of different kinds of pipe to suffer damage due to electrolysis has often been discussed, and there appears to be a well defined feeling in many quarters that a marked difference of this sort exists. It seems to be the general impression that cast iron pipes are much less susceptible to electrolytic damage than wrought iron or steel pipes. Experience indicates that cast iron pipe does offer less trouble from electrolysis than other kinds under most conditions. It has long been well known, of course, that certain kinds of iron are more resistant to self corrosion than others, wrought iron, as a rule, being more durable under ground than steel, and cast iron suffering less than either. Since the experimental data presented later in this paper show that the natural corrosion is affected in a marked degree by the presence of stray currents, it might reasonably be supposed that different kinds of pipes would also suffer in widely varying degrees from stray current corrosion. In order to determine to what extent this might be the case a considerable number of experiments have been carried out, using different kinds of iron that are employed in commercial service for underground pipes. Four kinds of iron were used, namely, ingot iron, which is the purest commercial iron known, wrought iron, machine steel and cast iron. Two series of experiments were run on cast iron, in one of which the cast iron was machined to a clean surface and in the other the iron was used just as it came from the mold without removal of the scale. The test specimens weighing about 30 grams each were placed in a red clay soil practically saturated with water and run in series on a constant current so that the same number of ampere hours was discharged

from each test specimen. The results are shown in Table VII. Since the current in all specimens was the same, and the size of the test specimens practically the same, giving about 0.2 milliamperes per sq. cm., the figures shown in the column under "electrical loss" are directly comparable for the different kinds of iron, and show the relative tendency of the iron to corrode electrolytically under conditions of the test.

TABLE VII

COMPARATIVE CORROSION EFFICIENCY FOR INGOT, WROUGHT AND CAST IRON AND MACHINE STEEL

No.	Total loss	Self corrosion	Electrical loss (Check in can)
	1—INGOT IRON		
0	1.704 g.	0.015 g.	1.689 g.
3	1.678	0.033	1.645
4	1.848	0.051	1.797
5	1.669	0.031	1.638
6	1.791	0.043	1.748
7	2.243	0.046	2.197
8	1.665	0.041	1.624
9	1.583	0.074	1.509
10	1.688	0.036	1.652
11	1.713	0.060	1.653
12	1.706	0.033	1.673
13	1.676	0.042	1.634
14	2.167	0.055	2.012
15	1.661	0.028	1.633
16	1.679	0.076	1.603
17	1.674	0.046	1.628
18	1.648	0.058	1.590
19	1.647	0.057	1.590
		Ave. 0.046	Ave. 1.695
	2—MACHINE STEEL		
20	1.658	0.052	1.606
23	1.734	0.076	1.650
24	1.827	0.062	1.765
25	1.721	0.066	1.655
26	1.672	0.064	1.608
27	1.694	0.076	1.618
28	1.684	0.113	1.571
29	1.756	0.087	1.669
30	1.644	0.031	1.613
31	1.653	0.046	1.607
32	1.792	0.066	1.726
33	1.761	0.059	1.502
34	1.686	0.033	1.653
35	1.695	0.063	1.632
36	1.808	0.066	1.742
37	1.734	0.066	1.668
38	1.818	0.109	1.709
39	1.694	0.059	1.635
		Ave. 0.066	Ave. 1.652

No.	Total loss	Self corrosion	Electrical loss (Checks in can)
	3—Wrought Iron		
40	1.713	0.160	1.533
43	2.203	0.077	2.126
44	1.789	0.065	1.724
45	1.712	0.063	1.649
46	1.689	0.117	1.572
47	1.842	0.094	1.748
48	1.756	0.116	1.640
49	1.693	0.069	1.624
50	1.659	0.048	1.611
51	1.201	0.114	1.087
52	1.701	0.124	1.577
53	1.661	0.068	1.593
54	1.852	0.055	1.797
55	1.684	0.068	1.616
56	1.646	0.050	1.596
57	1.712	0.073	1.639
58	1.713	0.076	1.637
59	1.840	0.080	1.760
		Ave. 0.084	Ave. 1.696
	4—Cast Iron, Surfaced		
60	1.807	0.120	1.687
63	1.700	0.305	1.395
64	1.846	0.108	1.738
65	1.757	0.283	1.474
66	1.769	0.177	1.592
67	1.746	0.079	1.667
68	1.808	0.136	1.672
69	1.939	0.082	1.857
		Ave. 0.161	Ave. 1.635
	5—Cast Iron Unsurfaced		
70	1.712	0.136	1.576
71	1.435	0.255	1.180
74	1.810	0.047	1.763
75	1.709	0.060	1.649
76	1.868	0.245	1.623
77	1.710	0.135	1.575
78	1.662	0.252	1.410
79	1.712	0.060	1.652
		Ave. 0.149	Ave. 1.553

An examination of these figures shows that there is but little difference in the amount of corrosion in the different kinds of iron. This is particularly true of the wrought iron, machine steel and machined cast iron which show respectively 1.696, 1.652, 1.635 grams loss. The ingot iron showed a somewhat higher electrolytic corrosion than any of the others, which seems to be somewhat surprising in view of the fact that it has frequently been demonstrated that the self corrosion in the case

of ingot iron is less than others. The least corrosion of all was in the case of the unfinished cast iron, and this is probably due to the protective effect of the scale, but even here the difference is hardly great enough to be considered of practical importance. The conclusion that must be drawn from these figures is that the efficiency of electrolytic corrosion of the different kinds of iron pipes is practically the same. If we examine the columns showing the self corrosion in different kinds of iron we find very surprising differences. These check specimens were placed in the can along with the anodes and carefully shielded from the flow of current as in all previous cases. An examination of these data shows that the ingot iron gave the least self corrosion of all, the average for all the specimens being 0.046 grams. Machine steel came next with a total natural loss of 0.066 grams; wrought iron is third with 0.084 grams; and last, and most surprising of all, the self corrosion of the cast iron is very much higher, being 0.161 for the machined iron and 0.149 for the unfinished iron. This shows very little difference between the finished and unfinished cast iron in the matter of self corrosion in the presence of current flow.

The relatively high rate of self corrosion of cast iron as compared to the other kinds of iron tested is contrary to the generally accepted idea that cast iron is more resistant to self corrosion than wrought iron. It is not improbable that this impression in regard to the superiority of cast iron has grown out of the fact that cast iron structures are usually made relatively heavy and they also tend to corrode more uniformly than wrought iron or steel, both of which factors would tend greatly to increase the life of the former. The principal cause of the greater rate of self corrosion of cast iron appears to be the galvanic action set up between the free carbon and the iron. The carbon is distributed so uniformly throughout the mass, however, that no appreciable pitting results, and hence the corrosion is less conspicuous and also less important than the same amount of corrosion would be if not uniformly distributed as is usually the case with most other kinds of commercial iron. It should be pointed out here that these tests were carried out in the same kind of soil as that used in securing the data of Table I, and the partial analysis there given shows it to be low in chlorides, sulphates, carbonates and nitrates. It was likewise free from cinders, coke, etc., and hence is not to be regarded as a very corrosive soil. It is shown later in this paper that the chemical constituents in

the soil have a marked influence not only on the total corrosion, but also on the pitting, or uniformity of the corrosion, so that it should not be assumed that the relative values given here will hold for all soils.

The foregoing results show that the different kinds of iron do not in themselves differ materially as regards their tendency to corrode electrolytically. It would appear from this that the differences noted in practise particularly in favor of cast iron are due to various other causes as has already been pointed out by Prof. Ganz and others, namely, higher resistance joints, higher specific resistance of the iron, the heavier walls, and a tendency to corrode more uniformly.

8 *The Effect of Certain Chemicals on the Corrosion of Wrought Iron in Earth.* When pipes are buried in the streets, they are subject not only to the action of the moisture and various natural constituents of the soil, but also to the effects of such chemicals as may result from the traffic on the streets, or from other sources.

A large amount of work has been done by other investigators on strips of iron immersed in aqueous solutions and it has been shown that the resulting corrosion is a function of the amount as well as the character of the chemical used. In many cases the tendency towards self corrosion first increases with the concentration and later diminishes very rapidly, possibly to zero, when the concentration is sufficiently increased.

It is well known also that certain solutions, such as alkalis, chromates, etc., tend strongly to inhibit electrolytic corrosion, at least when such solutions are practically pure. Hayden has shown that solutions of chromates, for example, tend to produce passivity in iron and thus prevent electrolytic corrosion, but that this passivity is destroyed by the addition of a few hundredths of one per cent of a cholride or a somewhat greater quantity of sulphate. It was considered advisable to carry out a series of experiments with iron imbedded in earth to which various chemicals had been added.

For these experiments a number of acids, bases and salts as indicated in Table VIII were secured and two grams of each were added to 300 g. of distilled water. The solution was added to 700 gr. of air-dried red clay, which had been sifted through a 20-mesh sieve. This earth contained initially about 5 per cent of moisture so that the resulting mixture contained about 33 per cent water which produced a fairly wet earth. The

TABLE VIII

EFFECT OF CHEMICALS ON CORROSION RESULTS

Chemical	Can No.	Solubility gm. per liter	Solution used gm. per liter	Chemical value gm. per liter	Critical value gm. per liter	Limiting value gm. per liter	Efficiency of corrosion at 0.55 ma. per sq. cm.	Natural loss mg. per sq. cm. per day	Corrosion eff. obtained by Hayden 1% sol., 22 m.a. sq. cm.
								B. S.	
CH_3COOH	2		5.715	0.0957			102.5	0.109	
$KMnO_4$	28	63.4	5.715	0.0364	0.1	0.1–1.0	90.2	0.166	
$BA(NO_3)_2$	34	92.0	5.715	0.0441			123.2	0.150	
$(NH_4)NO_3$	10	1924.0	5.715	0.0719	0–500	1155	116.3	0.265	37.8
Na NO_3	16	880.0	5.715	0.0677	0.1	632	104.2	0.152	
K NO_3	22	316.0	5.715	0.0571			89.6	0.238	25.0
H NO_3	4		5.715	0.0914			85.4	0.506	
Average							103.7	0.262	
Ba $Cl_2(2H_2O)$	31	357.0	4.874	0.0479	0	374	106.0	0.136	
Ca $Cl_2(2H_2O)$	25	427.0	2.890	0.0526			101.8	0.159	
H Cl	1		5.715	0.1579			101.6	0.270	
NH_4Cl	7	372.0	5.715	0.1076	1.0	290	101.4	0.496	102.3
K Cl	19	340.0	5.715	0.0772	50.0	299	98.6	0.222	102.2
Na Cl	13	3582.0	5.715	0.0985	0	395	97.8	0.239	
Average							101.2	0.253	
$Na_2SO_4(10H_2O)$	18	194.0	2.520	0.0360	10.0	400	89.2	0.136	
K_2 SO_4	24	111.0	5.715	0.0661	0—	108	88.9	0.170	102.8
Ba SO_4	36	0.002	5.715	0.0494			87.7	0.231	
H_2 SO_4	6		5.715	0.1174			87.4	0.329	
$(NH_4)_2CO_4$	12	754.0	5.715	0.0873	0.200	534	86.0	0.316	102.7
Ca $SO_4(2H_2O)$	30	2.0	4.520	0.0669	0		85.9	0.174	
Average							87.5	0.226	

TABLE VIII. *Continued.*

EFFECT OF CHEMICALS ON CORROSION RESULTS

Chemical	Can No.	Solubility gm. per liter	Solution used gm. per liter	Chemical value gm. per liter	Critical value gm. per liter	Limiting value gm. per liter	Efficiency of corrosion at 0.55 ma. per sq. cm.	Natural loss mg. per sq. cm. per day	Corrosion eff. obtained by Hayden 1% sol., 22 m.a. sq. cm.
								B S.	
$Ba(OH)_2$ $(8H_2O)$	32	39.0	3.104	0.0365	0	3.1	93.1	0.322	
NH_4OH...... ...	8	526.0	11.770	0.6965			88.7	0.591	
K $OH(2H_2O)$.....	20	1120.0	3.480	0.0348			85.6	0.611	
Na $OH(1H_2O)$....	14	1090.0	3.942	0.0993	0.1	1.0	81.7	0.608	
H OH(Av.)......	3& 33						73.9	0.258	
Ca $(OH)_2$........	26	1.6	5.715	0.1556	0	0 67–1.35	73.5	0.195	
Average.........							82.7	0.431	
K_2 CO..........	21	1120.0	5.715	0.0834	1.0	1–10	89.3	0.306	2.75
$Na_2CO_3(10H_2O)$.	15	275.0	2.107	0.0201	1.0	10	85.4	0.394	
$(NH_4)_2CO_3$.... ..	9	1000.0	5.715	0.1225			81.7	0.561	38.2
Ca CO_3.....	27	0.01	5.715	0.0719	0.0003	0.28	66.2	0.348	
Average.........							80.6	0.402	
$BaCrO_4$.........	35	0.004	5.715	0.0455			45.0	0.189	
$(NH_4)_2CrO$.. ...	11	405.0	5.715	0.0762			0.4	0.003	
$CaCrO_4$ $(2H_2O)$..	29	142.0	4.643	0.0600			0.3	0.136	
K_2CrO_4....	23	632.0	5.715	0.0593	0	0.1 up	0.3	0.163	
$Na_2CrO_4(10H_2O)$	17	813.0	2.829	0.0354			0.3	0.082	
CrO_3....	5	657.5	5.715	0.1143	0	0.01–0.05	0.2	0.122	
Average.........								0.116	

whole was thoroughly mixed and placed in a quart tin fruit can provided with a friction top.

The anodes were prepared as in experiments already described and vessels of water were placed in the cans as in previous experiments and the cans connected in series; first, in one group, finally, on account of increased resistance, in three. The current was adjusted daily to 0.005 ampere which gave a current density of discharge of about 0.45 milliampere per sq. cm.

At the end of 85 days the experiment was discontinued, the cylinders cleaned as previously described and the losses computed.

In Table VIII the substances have been grouped according to the anions formed.

Since in a number of cases more salt was used than the water could dissolve, the solubility of each chemical has been indicated. This is followed by the number of grams of the anhydrous salt used, per liter of water. Then follows the chemical value of the solution, *i.e.*, the number of grams of salt per liter of water multiplied by the hydrogen value of the anion and divided by the molecular weight of the salt.

Then follow two columns of values obtained from Hein & Bauer's " On the Attack of Iron in Water and Aqueous Solutions."[5] The first is the concentration of solution giving maximum corrosion; the second the concentration producing passivity or minimum corrosion. Hein and Bauer suspended small iron plates in beakers of solutions of concentrations from zero to saturation. Their researches in this line are more extensive than any other work so far reported.

While their experiments cannot be compared with the one now recorded on account of differences in conditions the values quoted may indicate at what part of the corrosion-concentration curve the present tests were made, from which we may form some estimate as to the manner in which the corrosion would have changed if the concentration were varied. The efficiency of corrosion is given in the following column, and this is followed by the natural loss in milligrams per sq. cm. of surface of the iron per day.

Referring to the efficiencies of corrosion given in column 8 it will be seen that with the exception of chromium compounds the efficiencies of corrosion are comparatively high.

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5. " *Mitteilungen aus dem Königlishen Material prüfungsamt.*", 1908 Berlin 26, 1.

All of the soluble chromates seem to protect the iron from electrolytic corrosion though this protection is not quite complete. In the case of chromium trioxide the loss at the anode was slightly less than that of the check specimen. No significance should be attached to this result until after further investigation. The comparatively slight protection shown by barium chromate is no doubt due to its very slight solubility.

None of the other chemicals which Friend, Hein and Bauer or Hayden have found to render iron passive in solutions seem to have been effective. Indeed, excepting the chromates there are but two values less than the average corrosion efficiency when distilled water was used.

The anodes in cans containing chromates were blackened and making the iron cathode in 2 per cent $H_2 SO_4$ for half an hour did not remove the discoloration. The check specimens were not discolored in this way.

That the hydroxids did not protect the iron may have been due to the presence of materials in the soils which neutralized them. There was no doubt quite a little CO_2 in the soil since it had been dried, crushed and sifted in the laboratory and had stood there in an open barrel for some time, and this may have been sufficient to counteract the effect of the hydroxids.

As will be seen by comparing columns 4 and 7 the concentrations used in the case of the hydroxids and carbonates were in nearly every case greater than those producing passivity when the solution alone acts on the iron. The difference in the results may be due to the effect of the earth on the solution or to the effect of the current. It seems clear, however, that the conditions which prevent self corrosion are not in general those which will maintain passivity in the case of anodes discharging current at moderate current densities. There does not appear to be any very definite relation between the corrosion efficiency observed and the self corrosion. The nitrates and chlorides for instance show respectively 103 and 101 per cent efficiencies of corrosion with corresponding value of self corrosion of 0.262 and 0.263 mg. per sq. cm. per day. The hydroxids and carbonates show lower corrosion efficiencies, namely, 82 and 80 per cent respectively, but the natural corrosion is much higher, being 0.431 for the hydroxid and 0.402 for the carbonate. The soluble chromates show almost a complete absence of electrolytic corrosion; whereas the self corrosion, although smaller than in the other cases, is by no means so small in proportion. It will be seen,

also, that the corrosion efficiencies observed do not agree with the values found by Hayden.[6] and shown in column 10. While a part of this difference may be due to the differences in solution strength and current density, it is probably due for the most part to the fact that the tests in the present instance were carried out with anodes imbedded in earth, whereas the experiments of Hayden were carried out in water solutions.

It does not seem probable that a sufficient quantity of inhibiting chemicals can be added to the soil surrounding a buried pipe to protect it indefinitely at a reasonable cost. To render the pipe passive is one problem; to maintain it passive against fluctuating, or even reversing currents regardless of the action of the soil and the constantly changing soil waters on the soluble chemical, is quite another.

A phenomenon of importance which is not shown in the tabulated data, is the pitting of the iron. This is usually attributed to particles of impurities in the surface of the iron or to variations in the soil. In these experiments the virgin soil was dried, rolled and sifted through a 20-mesh sieve. Enough solution was added to nearly saturate the soil. All of the cylinders were cut from the same piece of Norway iron rod. It might be expected, therefore, that the pitting would be very similar in all cases. This, however, was by no means the case. The anodes from the nitrate cans were covered by a dark cheese-like layer which maintained the original form of the anode. When this was pared off the surface of the iron was nearly smooth showing the fibrous structure of the wrought iron but no pits. The anodes in the cans containing sulphates were corroded almost as uniformly, but the surface of the cleaned anodes was brighter and somewhat uneven but with no marked pits. The surface of the anodes from the carbonate cans was more uneven. Pitting is noticeable in the case of the hydroxides and very marked in anodes from the cans containing chlorides.

As has been stated the soluble chromates blackened the surfaces of the anodes but did not materially attack them otherwise. There are no marked differences in the appearance of the check specimens except that those from the chromate cans remained bright. So marked are the differences in the anodes that in most cases it is possible to classify them by their appearance without reference to their numbers.

As underground pipes are almost always destroyed by pitting

6. *Journal of the Franklin Institute*, Vol. 172, pp. 295.

rather than by the amount of iron lost, a satisfactory means of preventing pitting would be of great value. The remedy most commonly suggested is the use of a more homogeneous iron. Without doubt this would reduce the corrosion due to local galvanic action, but the above experiments indicate that pitting of buried iron is very largely influenced by the nature of the electrolyte in the soil.

It may seem that for comparing the effects of different chemicals quantities which are chemically equivalent should be chosen. A glance at columns 5 and 8 will show that in a number of cases practically equal corrosion efficiencies occur when the chemical values are very different. Indeed, so far as the tables go, there seems to be no relation between chemical values and corrosion efficiency.

It appears from these experiments that solutions which produce passivity when iron is immersed in them do not protect the iron against electrolytic corrosion when the solutions are in earth, and with the exception of the chromates, no chemicals here tried are of marked value in reducing corrosion. Also the action of iron in solutions is not a safe criterion of its behavior when the iron is made anode in earth containing these solutions.

9. *Efficiency of Corrosion in Soils from Different Sources.* While the foregoing experiments show the effect of the different factors which influence electrolytic corrosion in soils, it naturally raises the question as to what extent these various factors are acting in the case of iron pipes subjected to electrolysis under practical conditions. This question seems to be best answered by actually carrying out experiments on electrolytic corrosion in a great variety of soils of different kinds, and gathered from widely different sources, at the same time maintaining the conditions as near to practical conditions as possible. In order to do this, corrosion tests were made on a large number of samples of soils which were gathered from various cities and sent to the Bureau of Standards at Washington for test as to their various physical properties. Ninety seven such samples were used for these corrosion tests which were taken from various places in Philadelphia, Pittsburgh, Erie and Apollo, Pa., St. Louis, Mo., Butte, Mont., and Albuquerque, New Mexico. Practically all of these soil samples were taken from excavations made for the purpose of examining pipes and were taken at about the same depth as the pipe in most instances. In all cases the samples were put at once into hermetically sealed cans

and kept therein until ready for test. For the purpose of making the corrosion tests, the soils were divided into two classes. Those soils from Philadelphia, St. Louis, Butte and Albuquerque were saturated with distilled water and kept so throughout the tests. The current density of the discharge averaged about 0.0002 ampere per square centimeter. The soils from Pittsburgh, Erie and Apollo, Pa., were tested with the same moisture content which they had when taken from the ground, and the current density was maintained at about 0.001 ampere per square centimeter. We thus have for one set a very wet soil and a rather low current density and in the other a rather high current density with what may be considered as roughly average moisture content, since at the time the samples were taken the soil was neither unusually wet nor unusually dry. The results of these efficiency of corrosion tests are given in Table IX. An examination of specimens 1 to 85 in which the earth was very wet and the current density low, shows quite high efficiencies of corrosion, the extreme ranges being 87.9 per cent for specimen No. 2 and 126.3 per cent for No. 30. All but two show values exceeding 100 per cent, while the great majority fall between 100 per cent and 115 per cent, the average of all being about 107 per cent.

The figures in the second group show much lower values, the extreme range being between 36.3 per cent and 104.3 per cent. Most of the values fall between 60 and 100 per cent with an average for all specimens of about 76 per cent. The difference between the efficiencies of corrosion shown by the two series is evidently due partly to the lower moisture content and higher current density in the latter case. These results are in accord with the data already presented in which the effects of moisture and current density have been studied separately. It should be pointed out here that while the current density in the second series is higher than may be expected under average conditions in practise, it is no higher than would frequently be encountered under moderately severe practical conditions. From these and the preceding tests it will be evident that under average practical conditions we may expect the corrosion efficiency to be of the order of 100 per cent when the earth is very wet and the current density quite low, while as the moisture content is reduced or the current density increased, the corrosion efficiency falls off and will usually be found to range between 50 and 110 per cent, while in quite dry soils, such as might at times be encountered in prac-

TABLE IX

CORROSION EFFICIENCY TESTS ON SOILS FROM DIFFERENT SOURCES

A

Rod No.	Total loss	Self corrosion	Electrical loss	Theoretical loss	Corrosion efficiency
1	2.294 g.	0.114 g.	2.180 g.	1.867 g.	116.8
2	1.811	0.170	1.641		87.9
3	2.147	0.062	2.085		111.9
4	2.244	0.195	2.049		110.0
5	2.327	0.090	2.237		119.8
6	2.203	0.117	2.086		112.1
7	2.156	0.075	2.081		111.9
8	2.244	0.175	2.069		111.0
9	2.273	0.089	2.084		116.7
10	2.363	0.133	2.230		118.8
11	1.881	0.064	1.817		97.3
12	2.103	0.174	1.929		103.4
13	2.173	0.126	2.047	1.876	109.2
14	1.992	0.025	1.967		104.8
16	2.584	0.280	2.304		122.8
17	2.186	0.041	2.145		114.4
18	2.207	0.032	2.175		115.9
19	2.052	0.086	1.966		104.8
21	2.058	0.091	1.967		104.8
22	2.187	0.130	2.057	1.871	109.9
23	2.168	0.203	1.965		105.0
24	2.091	0.044	2.047		109.4
26	2.239	0.078	2.261		120.9
27	2.398	0.112	2.286		122.3
29	2.091	0.068	2.023	1.895	107.0
30	2.497	0.108	2.389		126.3
32	2.190	0.044	2.146		103.6
33	2.130	0.079	2.051		108.4
34	2.068	0.061	2.007		106.0
37	2.310	0.170	2.140		113.2
38	2.114	0.097	2.017		106.4
39	2.362	0.085	2.277		102.4
41	2.300	0.025	2.275		120.2
42	2.313	0.155	2.158		113.7
43	2.161	0.150	2.011	1.913	105.0
44	2.148	0.094	2.054		107.3
45	2.202	0.031	2.171		113.4
46	2.105	0.182	1.923		100.7
47	2.257	0.101	2.156		112.8
48	2.489	0.351	2.138		111.7
49	2.126	0.022	2.104		110.2
50	2.177	0.121	2.056		107.3
51	2.188	0.122	2.066		107.9
52	2.305	0.104	2.201		116.1
53	2.200	0.148	2.052		107.3
54	2.250	0.228	2.022		105.7
55	2.108	0.052	2.056		107.4
56	2.330	0.117	2.213		115.6
57	2.252	0.115	2.137		111.7

TABLE IX—Continued

CORROSION EFFICIENCY TESTS ON SOILS FROM DIFFERENT SOURCES

Rod No.	Total loss	Self corrosion	Electrical loss	Theoretical loss	Corrosion efficiency
58	2.206	0.156	2.050		107.2
59	2.258	0.247	2.011		105.2
60	2.194	0.133	2.061		107.8
62	1.318	0.054	1.264		66.2
63	2.201	0.143	2.058		107.6
64	2.242	0.068	2.174	1.866	117.2
65	2.224	0.157	2.067		116.3
66	2.295	0.060	2.235		121.0
67	2.085	0.045	2.040		109.9
68	2.164	0.060	2.104		113.4
69	2.276	0.181	2.095		112.9
71	2.225	0.096	2.129		114.7
72	2.210	0.156	2.054		110.8
73	2.152	0.020	2.132		104.9
74	2.070	0.096	1.974		106.4
75	2.190	0.100	2.090		112.6
76	2.062	0.038	2.024		109.2
77	2.200	0.072	2.128		114.6
78	2.089	0.151	1.938		104.4
79	2.063	0.114	1.949		105.1
81	2.286	0.064	2.222		119.8
82	2.152	0.157	1.995		107.5
83	2.330	0.135	2.195		108.3
84	1.706	0.188	1.518		81.8
85	2.062	0.003	2.059		111.0
	B—Pittsburgh, Pennsylvania, Soils*				
	4.600	0.207	4.393	4.97	88.4
	5.100	0.177	4.923		99.2
	3.953	0.295	3.658		74.7
	2.780	0.220	2.560		51.6
	5.210	0.030	5.180		104.3
	4.368	0.005	4.363		87.8
	5.195	0.140	5.055		101.6
	2.822	0.270	2.552		51.4
	3.005	0.140	2.865		57.7
	4.435	0.145	4.290		86.4
	3.519	0.546	2.973		67.2
	4.272	0.545	3.727		72.0
	C—Erie Pennsylvania, Soil*				
	4.932	0.185	4.747	4.75	99.9
	3.499	0.250	3.249		68.2
	4.692	0.255	4.437		94.0
	3.595	0.129	3.466		72.9
	4.777	0.245	4.532		74.4
	18.180	1.451	17.729		80.7
	7.531	0.040	7.491		36.3

*Current density, one milliampere per square centimeter.

No. 1 to 37 inclusive taken from Philadelphia Nos. 38 to 47 taken from Norristown Pa. Nos. 48 and 49 from Albuquerque N. M. Nos. 50 to 84 from St. Louis Mo.

tise, a much lower figure might occur. We are convinced that under average conditions of soil moisture, and with current densities that may be expected in localities where electrolysis conditions may be considered moderately severe, a corrosion efficiency between 50 and 110 per cent will usually prevail. It will be seen also from the foregoing data that the decrease in corrosion efficiency due to increased current density is by no means as rapid as the increase in current, so that within the limits of current density that will usually be encountered in practise the actual amount of corrosion will be found to increase with increase of current.

The question may well be raised as to the reliability of corrosion efficiency experiments carried on in earths in the laboratory, and the extent to which such results may be considered as representing what would take place in the earth under normal conditions. In general, however, it will appear that experiments made in the laboratory are much more satisfactory for studying the laws of corrosion because conditions can then be much more readily controlled, and it is simply necessary to determine whether or not the laws of corrosion are substantially the same in the case of experiments on iron imbedded in small samples of soil as they would be if the iron were imbedded in the earth out of doors all other conditions being the same. This would probably not be true if the experiments were continued over a great length of time during which certain soluble constituents of the soil in the laboratory specimens might become exhausted by the corrosive processes, but we have ample reason to believe that experiments thus made and extending over a comparatively short time represent quite closely what may be expected to take place in the case of pipes under actual conditions. Numerous experiments have been made on specimens of iron imbedded in the earth out of doors in order to check this conclusion and to guard against any serious error that might be introduced by possible conditions of the soil. Some of the data bearing on this have already been given in the earlier part of this report relating to the effects of depth of burial and of current density on efficiency of corrosion, which show that for similar conditions the results for the out door tests do not give results materially different from the indoor tests. Another series is given in Table X. In this case a number of specimens of iron were buried in the earth out of doors and caused to carry current for several months, and the efficiency of corrosion was

determined. The current density varied considerably during the experiments due largely to change in resistance of the soil, but on the whole the range of current density averaged about the mean of the values used in the tests on effect of current density given above. The moisture content, of course, varied considerably from time to time.

An examination of Table X shows that the efficiencies of corrosion in these out-door tests ranged between approximately the same limits as those carried on in-doors for similar ranges of moisture and current density. These data afford additional evidence that the results of the corrosion efficiency experiments carried out on samples of iron imbedded in soils in the laboratory

TABLE X
EFFICIENCY OF CORROSION
SPECIMENS BURIED IN GROUND OUT OF DOORS

No.	Total loss	Self corrosion	Electrical loss	Efficiency of corrosion
1	15.719g.	0.286g.	15.433g.	74.9
3	12.153	0.286	11.873	72.8
5	4.425	0.282	4.143	61.5
6	5.879	0.282	5.597	73.9
7	5.894	0.280	5.614	80.0
10	6.374	0.280	6.094	96.3
11	2.364	0.278	2.086	83.3
12	3.310	0.278	3.032	76.8
				Ave. 77.9

are of substantially the same order of magnitude as they would be if the iron had been buried out of doors.

10. *Causes of Variations in Efficiency of Corrosion.* The causes which give rise to corrosion less than the theoretical amount according to Faraday's law have been the subject of much investigation by numerous investigators in connection with studies of passivity in iron. Numerous theories have been evolved, but comparatively little is definitely known in regard to this subject. The subject is too complicated and would lead to too much theoretical detail for us to go into here. On the other hand no attention has been given to the influences that may be responsible for corrosion efficiencies greater than 100 per cent, and in view of the frequency with which these high efficiencies of corrosion occur it seems well to present here very

briefly a few comments as to the possible causes that may be responsible for these high values.

It has been seen that the efficiency of corrosion of iron imbedded in earth in many cases exceeds 100 per cent, although we have not been able to confirm the results of other investigators previously referred to in this paper who have reported electrolytic corrosion amounting to several times the theoretical value. The highest values which we have found in our experiments have been of the order of 150 per cent but for the most part the corrosion has not been greater than 20 per cent in excess of the theoretical amount. The very large number of cases, however, both among the tests already described and among those that follow, in which the corrosion efficiency exceeds 100 per cent, even after careful correction has been made for self corrosion, indicate quite clearly that the loss of iron due to the discharge of electric current is in many cases appreciably greater than the theoretical amount. This is a matter of great importance and is being given special attention with the view of throwing further light on its causes, but much yet remains to be done before the phenomena can be properly understood.

Several causes suggest themselves as possible factors in producing this high efficiency of corrosion, some of which are discussed below.

(a). *The Formation of New Galvanic Couples.* It is well known that when iron corrodes in the presence of water and oxygen, oxides of iron are formed as end products. Under most underground conditions these will be deposited at the surface of the iron in more or less irregular contact with the iron. These oxides are fairly good conductors and are also electro-negative against iron, so that when a particle of iron oxide comes in actual contact with the iron, a galvanic element is formed which tends to corrode the adjacent iron. It seems not improbable therefore that when a clean piece of iron is subjected to the discharge of electric current the formation of the iron oxide which results from the initial corrosion may set up galvanic couples which did not before exist and thus greatly increase the self corrosion on the specimen.

The following experiments were carried out to gain an idea of the effect of the initial corrosion products on subsequent electrolytic corrosion and on the self corrosion of the specimen. In this experiment, twelve two-quart tin cans were coated outside with paraffin, and a layer of heavy paraffined paper placed

over the sides. The cans were then nearly filled with red clay which had been air dried two months, and sifted through a 20-mesh sieve; 300 g. of distilled water was added to 700 g. of this sifted earth, and the whole thoroughly mixed before it was packed in the cans. This earth was nearly saturated with water. For anodes and check specimens cylinders of $\frac{1}{4}$-inch (6.3 mm.) Norway iron, 2 in. (5.08 cm.) long, were used. The cylinders were carefully cleaned and placed vertically in the cans, the anodes in the center and the check specimens close to the side, and carefully shielded from current flow. A small vessel of water was placed within each can to retard evaporation of the moisture in the earth.

The twelve cans were then connected in series on a 115-volt circuit; the cans serving as cathodes. The current was kept practically constant at 10 milliamperes.

At the end of 429 hours, eight cans were removed from the circuit. Four of these were set aside unopened. From the other four the cylinders were removed, cleaned, weighed, and replaced, and the four cans were then replaced in circuit.

At the end of 686 hours more, the cans were opened, the cylinders cleaned, weighed, and the losses computed. When the cylinders were washed in warm water, practically all of the rust came off, so that it was necessary to clean them electrolytically for but a few minutes to obtain a bright surface.

The corrosion of the anodes was more uniform than in most previous experiments, but the corroded surface was somewhat uneven, the loss being greatest near the centers of the cylinders. There was practically no pitting of the check specimens.

The results of the experiments are shown in Table XI. Here the specimens are divided into three groups, *A*, *B*, and *C*. In group *A* the current was kept on the specimens during the first period of 429 hours and then switched off, but the specimens were permitted to stand in the soil undisturbed during the second period of 686 hours, after which they were taken out and weighed and the efficiency of corrosion determined. In this case if the initial corrosion due to the electric current tended to accelerate self corrosion we should expect a higher efficiency of corrosion than if the specimens had been removed as soon as the current was shut off. In group *B* the specimens also carried current during the first 429 hours, but were removed from the earth, cleaned and weighed as soon as the current was shut off and then put back in circuit again. If the self corrosion is

greater, due to the initial electrolysis we should expect that the efficiency of corrosion would be smaller for the first period in group *B* than was obtained for group *A*. The table shows that such was the case, although the difference is quite small and

TABLE XI

EFFECT OF INITIAL PRODUCTS ON SUBSEQUENT CORROSION

Area of exposed metal, 7.6 sq. cm. Current density about 1.2 milliamperes per sq. cm. Moisture in soil about 30 per cent.

No.	Total loss	Self corrosion	Electrical loss	Efficiency of corrosion
		Group A		
2	4.270g.	0.085g.	4.185g.	102.8
6	4.408	0.085	4.323	106.3
7	4.365	0.085	4.280	105.2
12	4.370	0.085	4.285	105.3
				Ave. 104.8
		Group B. 1st Period		
1	4.230	0.045	4.185	102.8
3	4.226	0.045	4.181	102.7
13	4.225	0.045	4.180	102.7
14	4.273	0.045	4.228	103.8
				Ave. 103.0
		Second period		
1	6.316	0.080	6.236	87.8
3	6.645	0.080	6.565	92.5
13	6.475	0.080	6.395	90.1
14	6.823	0.080	6.743	95.0
				Ave. 91.4
		Group C		
4	11.185	0.149	11.036	99.0
5	10.658	0.149	10.509	94.3
8	10.275	0.149	10.126	90.8
9	10.945	0.149	10.796	96.9
				Ave. 95.2

may possibly be due to other causes. By cleaning these specimens and putting them back in the same soil in which they had previously run and maintaining the same current flow as before during the second period we could determine whether there was

any marked change in the efficiency of corrosion due to changes in the soil caused by the flow of current. The table shows that there was a marked difference here, the efficiency of corrosion being much lower during the second period than during the first. In group *C* the specimens were permitted to remain in circuit during both the first and second periods without interruption.

In comparing the results obtained from these three groups it is significant that the highest apparent efficiency of corrosion was obtained when the current was allowed to flow for a time and then removed and the specimen allowed to remain in the earth subjected to the action of self corrosion during the second period. The next largest apparent efficiency was obtained when the specimens were cleaned and weighed at the ends of the first period immediately after the stopping of the current. The lowest efficiency was obtained when the cleaned specimens of group *B* were returned to the same earth which had been previously used and again connected in circuit during the second period. Further group *C*, which ran continually throughout the first and second periods showed an intermediate value of corrosion efficiency. These results appear to show that there are two opposing tendencies at work, one of which is to increase the corrosion efficiency as in group *A*, due to some cause associated with the flow of current, and the other a tendency to decrease the corrosion efficiency as in group *C* due perhaps to depletion of certain ingredients in the electrolyte. Other experimental data given in this paper indicate that this tendency for the efficiency of corrosion to decrease with time may be due either to the exhaustion of dissolved oxygen or to a loss of moisture by the earth.

The check specimens used in these experiments also show the effect of current flow on the self corrosion of check specimens placed in the cans along with the anodes. Examining the data for group *B* under the column headed " Self corrosion " we find that during the first period the rate of corrosion was less than after the check specimens had been cleaned and returned to the same cans. By comparing the self corrosion in group *A* with those in groups *B* and *C*, the tendency is seen to be the same and even more marked. Further, by comparing the self corrosion of group *B* with that of group *C* we find that, although the total flow of current is the same, the corrosion is considerably greater in the latter. Since those of group *B* were removed once and

cleaned while those of group *C* were not, this result seems to support the theory that the presence of a small amount of initial corrosion tends to stimulate the self corrosion throughout the remaining period of the test. It should be borne in mind, however, that the figures on which this statement is based are subject to such large variations that they should not be accepted as conclusive until they have been repeatedly verified.

b. *The Depolarizing Effect of Oxygen.* According to the electrolytic theory of corrosion all iron contains sufficient differences in physical or chemical structure at different points on its surface to set up local galvanic elements which are supposed to be responsible for self corrosion. Under ordinary conditions of self corrosion therefore there will be certain points on the surface which will be anode points discharging current into the electrolyte and corroding the iron and there will also be near by cathode points at which the current reenters the iron. The amount of corrosion which results from these couples will, of course, depend upon the resistance of the local circuit as well as on the effective difference of potential which exists between adjacent points. When current flows in these local paths there is a tendency to form a film of hydrogen at the cathode points which diffuses but slowly, and this not only sets up a counter electromotive force but it likewise introduces a large amount of additional resistance into the local circuit. In consequence of this the self corrosion may be said to inhibit itself to a very considerable extent. If now we superpose on this specimen an electric current, making the specimen anode, more or less oxygen will be liberated near the surface of the metal which may react with the hydrogen, thus in effect depolarizing the local galvanic action and permitting much greater self corrosion in the case of a specimen discharging current than in a case of a similar specimen not discharging. This excess of self corrosion would always appear due to the main current flowing and would thus increase the apparent efficiency of corrosion. It is easy to see how this effect could increase the efficiency of corrosion from a low value up toward 100 per cent, although it would not in general tend to make the corrosion efficiency greater than 100 per cent.

c. *Non-uniform Corrosion of the Iron.* When iron corrodes it is always with greater or less irregularity. Pits may be formed in which a small hole on the surface may communicate with a large chamber below, and this pitting may pursue such an

irregular course as to eat entirely around particles of iron causing them to fall away from the test specimen. This seems particularly likely to happen in the case of very impure metals which often exhibit a more or less honeycombed aspect after long continued corrosion. Since the efficiency of corrosion is always determined from the net loss of weight any particles of iron that might be dislodged in this manner would be charged against the current and in this way the corrosion efficiency might easily be made to appear larger than 100 per cent.

d. *Circulation of the Electrolyte.* It is well known that if the electrolyte surrounding a piece of iron be kept in constant circulation the amount of self corrosion which results will be greater than if the electrolyte remains practically still. When an electric current flows through an electrolyte it causes a migration of the ions which may increase the self corrosion of the iron in a manner analogous to circulation of the electrolyte. Particularly, in the case of an anode there is a tendency for the acid radicals such as Cl, SO_4, etc., to concentrate near the anode surface and it is well known that liquids containing large amounts of these radicals, particularly the chlorine, produce very rapid corrosion of the iron. Here again any excess of self corrosion which would be produced would be charged against the electric current and a high efficiency of corrosion would result. It is not improbable that any or all of the above mentioned causes may be operating in certain cases to produce a high efficiency of corrosion. However, that may be, it has been definitely established that if a check specimen is imbedded in the earth along with the anode the self corrosion will always be much higher than if the check specimen is imbedded in the same earth but in a separate vessel. This is true even when ample precautions are taken to shield the check specimens from the flow of electric current. This is shown by the following series of experiments which is typical of a great many which have been carried out. The anodes were buried in the center of a quart tin can filled with earth, the can itself serving as the cathode. The check specimen was placed in the earth near the cathode and shielded from current flow by means of a glass shield semi-cylindrical in form and of considerably greater diameter and length than the check specimen. The arrangement is shown in Fig. 1. In many of these experiments, in addition to the check specimens placed inside the can, a second check specimen was also placed in the same kind of earth with the same moisture

content, but placed in a separate vessel through which no current passed. A few of these data which are typical of all are given in Table XII.

From this table it will be seen that the average self corrosion on the check specimens placed in the can carrying current was roughly 2.7 times that on the specimens in the cans through which no current passed, while the time in the latter case was 1.7 times that in the former thus making the average rate of self corrosion about 4.6 times as great in the can carrying current as in the one which carried no current. Further, it seems altogether probable from the foregoing discussion of causes of increased corrosion efficiency that the self corrosion on the anode itself would be considerably greater than that on the check specimen placed inside the same can, so that even though the electrolytic corrosion proper were to take place strictly in accordance with Faraday's law we should nevertheless obtain an experimental result indicating an efficiency considerably greater than 100 per cent.

TABLE XII

EFFECT OF CURRENT FLOW ON SELF CORROSION

Check No.	Loss of check with iron carrying current 49 days	Loss of check in separate vessel 83 days
7	0.075 g.	0.041 g.
14	0.025	0.022
21	0.091	0.025
28	0.038	0.022
35	0.048	0.045
42	0.155	0.057
63	0.143	0.063
83	0.135	0.018
84	0.118	0.014
	Ave. 0.092	0.034

In view of the foregoing therefore, it does not appear that we have any reason to suppose that the electrolytic corrosion proper does not take place in accordance with Faraday's law even though a corrosion efficiency of much more than 100 per cent is indicated. Nevertheless in computing corrosion efficiency it is proper to charge all of this excess of self corrosion against the electric current, since in the absence of the current it would not have occurred, and the corrosion directly chargeable to the current includes all of that which results from the passage of

the current, whether due directly to the current or to secondary causes brought into action by the current flow.

11 *Effect of Very Low Voltage.* In all of the foregoing experiments, although the current density has often been reduced to quite low values, the voltage impressed upon each pair of electrodes has in general been somewhat high, being of the order of several volts in most instances. This has been due to the fact that the small size of most of the electrodes used gave rise to so high a resistance in the earth that voltages of this order were necessary in order to produce the desired current density. Although there is no theoretical reason why the efficiency of corrosion should vary with voltage except in so far as it effects the current density, nevertheless it seemed very desirable to carry out a few experiments on very low voltages, particularly below one volt, in order to determine whether the efficiency of corrosion would be materially different with such extremely low voltages from what it is on the higher values. Accordingly three cells were made up using tap water as an electrolyte and thin sheet iron electrodes separated by several sheets of filter paper. This gave a very low resistance between the electrodes and made it possible to secure sufficiently large current on much lower voltages than had been possible in the case of specimens buried in soil. One of these cells was run on a constant potential of 0.1 volt, another on 0.6 volt, and the third at one volt. Current measurements were made at frequent intervals and the ampere hours determined. The results are shown in table XIII. It will be seen by reference to this table that the efficiencies of corrosion are comparatively high, being highest in the case of the one-volt cell and lowest in the case of the 0.6 volt cell, and intermediate in the case of the 0.1-volt cell. The current densities are given in the table and are seen to be extremely low, the lowest being but 0.003 of an milliampere per square centimeter. These results show quite clearly that there is no reason to expect that the corrosion efficiency changes materially at any critical value of voltage within a range that is of any practical consequence in the negative return of street railway systems.

II. EARTH RESISTANCE

The foregoing experiments show what may in general be expected under different conditions as to the discharge of current from iron electrodes buried in soils. In practise, however,

when investigating electrolysis conditions, we are not dealing with known conditions of current flow, since it is in most cases impracticable to measure directly leakage currents at any point in the soil without resorting to measures that are too tedious and expensive for most work. We have on the contrary certain easily determined voltage conditions throughout the negative railway return system, and hence, in order to properly interpret the data above presented relating to laws of corrosion, it is necessary to take into consideration the effect of earth resistance on the stray currents that may be carried by the pipes and discharged by them into the earth under known conditions as to potential differences in the network. It is not the purpose of this paper to go into detail in regard to the matter of earth resistance, as this is to be treated somewhat fully in another

TABLE XIII
LOW VOLTAGE TEST

Plate No.	Loss total	Electrical loss	Theoretical loss	Corrosion efficiency	Current density mill. amp. per sq. cm.	Voltage
1	0.496 g.	0.456 g.	0.467 g.	97.7	0.051	1.0
2	0.153	0.113	0.127	89.0	0.014	0.6
3	0.062	0.022	0.024	91.7	0.003	0.1

Area of anode, 47.47 sq. cm.
Ave. natural loss of anode 40 mg.

paper by the authors in a publication of the Bureau of Standards. The great importance of the subject of earth resistance however, in relation to electrolytic corrosion in soils makes it desirable to present here very briefly a few fundamental principles in regard to the resistance of soils and its relation to stray current electrolysis.

It is obvious that if the soil surrounding the pipe network possessed infinite resistance, there would be no trouble from electrolysis, since in that case no stray current could leak off of the tracks and hence find their way into the pipe. On the other hand, if the earth possessed zero resistance, we would also have no electrolysis, since in that case the earth would short circuit the pipes and prevent them from taking up the stray currents. Somewhere between these two extremes we will obviously have a value of earth resistance which, in any given case would pro-

duce a maximum of electrolysis trouble. The value of this resistance required to give a maximum electrolysis undoubtedly varies greatly with conditions; such as geometrical form of the pipe and track networks, kinds of joints used in pipes, size of pipes, resistance of rail return, and numerous other factors. We feel confident, however, from observations made under practical conditions that in most, if not all cases, the resistance of the earth will be found much higher than that required to produce maximum electrolysis, so that in general we may expect the electrolysis to be greater the lower the resistance of the earth. With a view of giving an idea of what may be expected in the way of earth resistance in practise, we present below a summary of some investigations which we have made in regard to variation of earth resistance with varying conditions, and following that we have given the results of a considerable number of earth resistance measurements made on a variety of soils taken from widely scattered sources. In making these earth resistance measurements several different methods were used, in some of which the earth was measured in place without being disturbed, while in other cases the samples were taken to the laboratory, packed in glass cylinders and the resistance measured between plastic amalgam electrodes pasted on the ends of the cylinder, the voltmeter-ammeter method with alternating current being used. In a good many cases both methods were used and the results were found to check in a very satisfactory manner. In making the earth resistance measurements in place two excavations were made side by side to a depth of several feet, leaving a portion of undisturbed earth several inches in thickness between the two excavations. The sides on this undisturbed portion were made approximately parallel and fairly smooth, and small electrodes a few inches in diameter placed on the opposite sides. These electrodes were then surrounded by guard rings of sufficient diameter to assure practically parallel lines of current flow between the two electrodes. The resistance of the earth between the electrodes was then measured by means of voltmeter ammeter methods as in the laboratory, alternating current being used for the purpose. In making these measurements care was taken to keep the electrodes and the guard ring not only at the same potential, but also to see that there was no displacement of phase between the e.m.fs. applied to them.

In making the tests in the laboratory, preliminary experiments showed that much more satisfactory results could be obtained

by compressing the earth in the testing machine to such a point that further increase in pressure caused practically no variation of resistance. It was found, and will be shown by the curves below, that with increase of pressure a point is soon reached beyond which the resistance varies but slightly with further increase in pressure. Careful comparison of results obtained by first measuring the resistance in place, in the ground, and later in the same earth in the laboratory, indicated that they were practically the same which ever method was used, and since the method of measuring the resistance in the laboratory was so much more rapid and convenient, this method was used for the great majority of measurements that are presented below.

12. *Effect of Moisture Content on Earth Resistance.* Moisture content is one of the controlling factors in earth resistance. In Table XIV is given a series of resistance measurements taken on a

TABLE XIV

RELATION BETWEEN THE AMOUNT OF MOISTURE IN THE SOIL AND ITS SPECIFIC RESISTANCE

Per cent moisture (in terms of dry earth)	Specific resistance ohms per centimeter cube
5.0	2,340,000
11.1	237,400
16.7	13,880
22.2	6,835
33.3	5,400
44.5	4,725
55.6	4,870
56.7	5,197
77.8	5,045

sample of red clay soil with varying moisture content, which may be regarded as more or less typical. For making each measurement a new sample of thoroughly dry earth, dried at 105 deg. cent. was taken and the required amount of moisture added, the percentage of moisture being expressed in terms of the dry earth. It will be seen that above about 22 per cent of moisture the resistance remains practically constant, but below this value, the resistance rises very abruptly with decrease of moisture content, and at 5 per cent of moisture the resistance has risen to considerably over four hundred times its value when the soil is saturated. This shows that the actual current flow to and from a pipe imbedded in soil is dependent in vastly greater degree on the moisture content than on the potential difference between the pipe and surrounding structure, and points to the fact that a potential difference which might be

perfectly safe in a high and well drained locality might be sufficient to give rise to a great deal of damage in a low and damp locality. This tendency has of course been well recognized, but it has not been given the consideration which it deserves. Cases frequently arise in which this fact might well be treated as an important factor in determining the location of a railway substation, and particularly the points at which insulated radial return feeders might best be connected to the tracks.

Another important practical aspect of this change in resistance with moisture content is its effect on the distribution of potential drops throughout the negative railway return area. Since the various parts of the pipe system are buried at different depths and are very irregularly located with respect to the tracks it is evident that changes in the moisture content with depth will exert a marked influence on the distribution of the resistance in the path of the leakage current, which in turn will greatly affect both the magnitude and distribution of the potential gradients throughout the system. For this reason not as much reliance should be placed on voltage surveys made at extremely wet and more especially at very dry periods as on those taken under more nearly average moisture conditions.

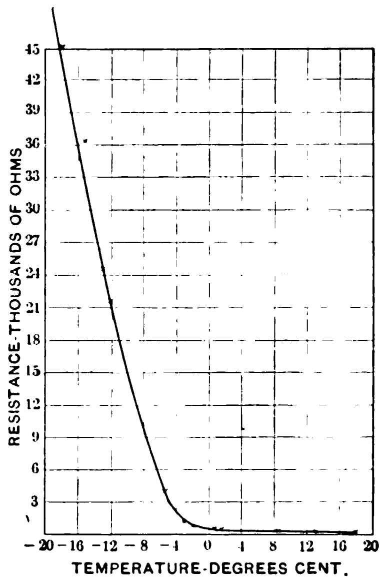


Fig. 8.—Resistance—Temperature Curve

13. *Effect of Temperature on Earth Resistance.* The effect of temperature on the resistance of soil was determined throughout the range from about 18 deg. cent. to − 18 deg. cent. (0 to 65 deg. fahr.). For this purpose a moist soil was used and was placed in a vessel surrounded by an ice-chamber in which a mixture of ice and salt was placed and the whole was allowed to stand until the temperature had reached about − 18 deg. cent. the resistance being measured from time to time by means of electrodes which were imbedded in the sample of earth and rubber covered leads brought out. The temperature of the

earth was taken at the same time each resistance measurement was made, an ordinary mercury thermometer inserted in the center of a hollow electrode being used. The results of these resistance measurements, as a function of temperature, are given in Table XV and are plotted in Fig. 8. By reference to the curve it will be seen that the resistance varies throughout very extreme ranges, even within the ranges of temperature variation that commonly occur in this country. Above freezing the resistance variation is much less marked, but even here we find that the resistance at zero deg. cent. is approximately 2½ times its value at 18 deg. cent. At about the point at which the soil water begins to freeze there is tremendous increase in the temperature coefficient of resistance, and as the temperature becomes lower the resistance rises enormously, and at − 18 deg. cent. the resistance is seen to be over two hundred times as great as at 18 deg. above zero.

TABLE XV

EFFECT OF TEMPERATURE ON RESISTANCE OF SOIL

Soil No. 32. Moisture 18.6 per cent. Specific resistance at 20 deg. cent. 6260 ohms per cu. cm.

Temperature cent.	Resistance ohms
18.0	224
13.0	286
8.5	398
1.5	458
1.0	462
0.0	542
− 2.0	940
− 3.0	1,185
− 5.5	4,340
−12 0	21,700
−13.0	24,600
−15.0	36,200
−18.0	45,000
−19.0	48,900

This enormous variation of earth resistance with temperature is of considerable practical importance and indicates that in moderately cold weather such as prevails in the northern cities, comparatively little trouble from electrolysis may be expected. This is due not primarily to the higher resistance of the earth immediately surrounding the pipes, since the pipes are usually located at a sufficient depth, so that the temperature of the earth immediately surrounding will not reach the lower values

used in this experiment. The real reason for the diminution of electrolysis trouble with the fall in temperature is the reduction of leakage current from the rails. It will be evident that when the ground is frozen even but a few inches deep, the resistance of the earth immediately surrounding the rail becomes enormously increased, and the leakage of stray currents into the earth is thereby correspondingly reduced. And since the rise in resistance with even a few degrees of frost may be many fold, it is apparent that but a thin layer of frozen earth about the rail would be necessary in order to produce a very marked increase

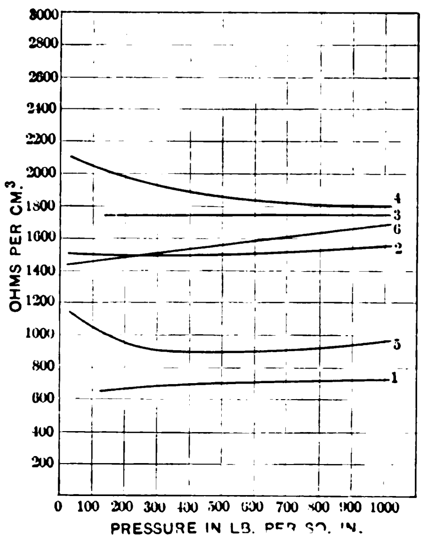


FIG. 9.—SPECIFIC RESISTANCE—PRESSURE CURVES OF EARTH

1—Blue clay, sample 51; 2—black humus, sample 52; 3—black humus, sample 59; 4—yellow clay, sample 56; 5—sand and humus, sample 64; 6—yellow clay and sand, sample 83.

in the total resistance of the path of the leakage current. This reduction in electrolysis troubles in cold weather due to increase in resistance of the earth is further augmented by the increase of the conductivity of the rail return which takes place at the lower temperature, which may amount to as much as 15 or 20 per cent, and is sufficient, as a rule, to compensate for the increased load which usually prevails during the cold period.

It should also be pointed out here that the effect of variations in temperature with depth on the resistance of earth will have an effect on the distribution of potential gradients in the earth very

similar to variations in moisture content referred to above. For this reason it is preferable not to make voltage surveys at times when extremely low temperatures prevail.

14 *Effect of Mechanical Pressure on Earth Resistance.* Of considerable interest, although of much less practical importance, is the effect of mechanical pressure on the electrical resistance of earth. As already stated when pressure is applied to a sample of earth its resistance is but little affected as a rule, after a certain relatively low value of pressure is reached. This is shown in Fig. 9, which gives resistance-pressure curves for a number of different soils from various sources. The range of pressures here are for the most part between twenty and one thousand pounds per square inch, and the variations in resistance between these limits are surprisingly small. Numerous measurements of the resistance of earth two or three feet below the surface before being disturbed using the guard ring method and subsequent measurements of the same earth in the laboratory under pressure show that the resistance at a few hundred pounds pressure per square inch is substantially the same as that of the undisturbed earth.

15 *Other Factors Affecting Current Flow.* There are other factors also which affect the resistance of soils, such as its mechanical properties, and chemical constituents and these may have an important bearing on current flow to and from the buried pipes. The character of the street railway roadbed is also an important factor in determining the extent of leakage of stray current into the earth. A well drained rock or concrete road bed may in general be expected to offer much higher resistance to the leakage of current than one in which the construction is such that a large amount of moisture is retained. Polarization and film resistances at the surface of the pipes may also be an important factor in current flow. As soon as an electromotive force is applied to a buried pipe the current flow drops off rapidly with time, especially during the first few minutes, due to the setting up of counter e.m.f.'s and the formation of film resistances. The extent to which this may occur in some cases is shown in Fig. 10, which shows the effective resistance as a function of time after the application of an e.m.f. of about six volts between two short lengths of cast iron pipe buried about twelve feet apart. From this it will be seen that the initial resistance of about 18 ohms has practically doubled within half an hour after the e.m.f. is applied, and after

that the resistance remains practically constant. In this case the effect of the polarization and film resistance is practically as great as the total soil resistance between the pipes. These results were obtained when the soil was very wet, and it is probable that in a comparatively dry soil the effect would have been less marked.

16 *Resistance of Soils from Different Sources.* In order to give an idea of the order of magnitude of the resistances that may be expected in practise, together with the range of variation of the same, we give herewith a table of resistances of soils taken from various points in the cities of Philadelphia and St. Louis and other cities. In all of these the specific resistance of the soil is measured with the same moisture content which it had when first taken from the ground and all were measured at about one temperature.

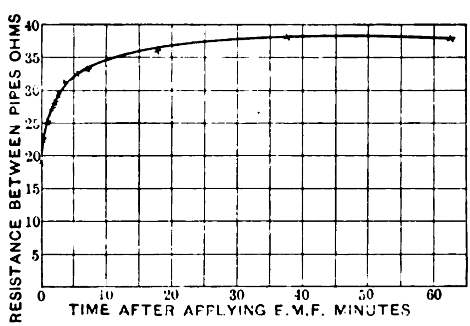


FIG. 10.—EFFECT OF POLARIZATION ON RESISTANCE BETWEEN BURIED PIPES

The soils from each city were taken from widely scattered points and represent a wide variety of different kinds of soils, as will be evident from the brief description. The moisture content was determined in each case and is given along with the other data. The results are shown in Table XVI. An examination of this table reveals some striking differences in two particulars: In the first place the specific resistances found in St. Louis shows a much greater degree of uniformity than those found in Philadelphia. The extreme range of values of specific resistance for St. Louis earths is between 400 and 1800 ohms per centimeter cube, while for Philadelphia the range is between 595 and 610,000 ohms per centimeter cube. The other chief point of difference is the magnitude of the mean value of resistance, the average value of the specific resistance for all the samples taken in St. Louis being 1053 ohms, while the average for the Philadelphia

TABLE XVI

SPECIFIC RESISTANCE OF SOILS

No.	Character	Per cent moisture	Ohms per cu. cm. Spec. resistance
	PHILADELPHIA SOILS		
1	Moist gray clay	11.7	651
2	" yellow clay	14.8	3,850
3	" blue clay	16.1	3,036
4	Nearly dry red sand	7.6	2,700
5	Moist red clay	17.4	8,820
6	Nearly dry mica schist	4.7	156,400
7	Nearly dry gray clay	16.2	5,930
8	" " clay, rock and cinders	17.9	595
9	Moist blue clay and gravel	13.1	2,830
10	Moist blue clay	15.3	1,605
11	Moist yellow clay	17.2	5,340
12	Moist yellow clay and sand	13.4	6,280
13	Wet gravel	11.0	24,550
14	Wet humus and clay	9.5	2,600
15	Moist clay, sand, cinders	17.4	2,060
16	Damp, disintegrated schist	12.9	12,100
17	Wet clay, cinders, gravel	16.9	5,000
18	Moist yellow clay	19.4	4,825
19	Moist yellow clay	17.3	3,820
20	Moist red clay	19.3	21,200
21	Moist yellow clay	15.6	25,900
22	" red sand and clay	15.7	13,700
23	" clay, cinders, sand	13.7	1,494
24	" clay and sand	20.0	821
25	Moist clay and sand	18.7	1,774
26	Damp clay and humus	16.7	2,490
27	Damp clay and humus	16.2	2,585
28	Nearly dry disintegrated schist	0.3	610,000
29	Damp yellow clay	16.8	2,250
30	Moist yellow clay	18.5	2,455
31	Saturated clay and cinders	23.8	4,410
32	Moist clay and sand	18.6	6,260
	ST. LOUIS SOILS		
50	Wet clay	20.4	600
51	Blue clay	21.1	700
52	Moist virgin soil	20.8	1,500
53	" yellow clay	21.5	1,250
54	Yellow clay	19.0	1,800
55	Yellow clay		1,600
56	" "	21.1	1,800
57	" "	22.8	1,400
58	Yellow clay	21.3	1,400
59	Virgin black soil	21.2	1,700
60	Yellow clay	16.0	1,800
61	Yellow clay	23.4	990
62	Yellow clay	18.4	700
63	Yellow clay	21.9	950
64	Sand and humus	17.8	925
65	Sand and humus	20.0	900
66	Blue clay	22.0	470
67	Virgin yellow clay	19.1	1,450
68	Virgin yellow clay	22.5	484

TABLE XVI—Continued

SPECIFIC RESISTANCE OF SOILS

No.	Character	Per cent moisture	Ohms per cu. cm. Spec. resistance
69	Yellow clay	22.0	700
70	Virgin yellow clay	20.0	1,700
71	Virgin soil	22.9	840
72	Yellow clay	23.3	900
73	Blue clay	26.1	400
74	Blue clay	19.1	600
75	Blue clay	24.2	830
76	Moist blue clay	23.1	500
77	Nearly dry yellow clay	16.4	1,100
78	Blue clay	17.1	650
79	Yellow and blue clay	26.9	600
80	Yellow and blue clay	19.7	820
81	Blue clay	20.0	750
82	Clay and loam	19.2	1,450
83	Sandy clay	19.5	1,600
84	Yellow clay	22.6	1,200
	PITTSBURGH SOILS		
33	Damp sand	13.4	4,506
34	Moist yellow clay	16.5	2,819
35	Moist clay and humus	20.5	2,300
36	Blue clay	26.5	14,025
37	Moist gray clay	26.3	619
38	Damp sand	13.0	1,335
39	Damp sand	10.2	8,709
40	Loam and cinders	21.8	1,074
41	Nearly dry sand	12.3	2,908
	ERIE SOILS		
42	Moist clay and gravel	6.0	18,080
43	Clay, coal and gravel	16.7	1,796
44	Wet blue clay	19.3	3,779
45	Moist blue clay and sand	11.9	3,080
46	Moist gravel	5.7	14,025
47	Wet blue clay and sand	19.6	2,462
	APOLLO, PA. SOILS		
48		30.5	1,796
	ALBUQUERQUE, N.M., SOILS		
85		15.3	43,960
86		11.1	59,475
87		11.9	41,908
	WASHINGTON, D. C. SOILS		
88	Air dry red clay	4	2,340,000
89	Nearly dry red clay	10	14,660
90	Moist loam	20	8,729
91	Wet yellow clay and sand	30	41,490
92	Wet humus clay and sand	30	24,060

samples was 28750 ohms per centimeter cube, the latter being over 27.3 times the former. It should be noted however, in making this comparison that the high average for Philadelphia is due to a large extent to the abnormally high resistance of two samples containing large quantities of mica, one of which had a specific resistance of 156,400 ohms and the other 610,000 ohms. If these two are eliminated the remaining 31 specimens show an average for Philadelphia of 5885 ohms per centimeter cube, which, however, is still over 5.6 times the value for St. Louis. It is quite probable that this difference is such as to prove an important factor in the electrolysis situation in the two places.

CONCLUSIONS

The following are some of the more general conclusions that may be drawn from the experimental data presented in this paper:

1. The current density has a marked effect on efficiency of corrosion of iron in soils, the efficiency of corrosion being in general greater the lower the current density. In saturated soils the corrosion may vary between 20 per cent and about 140 per cent for the range of current densities between 5 milliamperes and 0.05 milliampere per square centimeter.

2. Moisture content in the soil also has a marked effect on efficiency of corrosion. The corrosion efficiency being in general greater with increasing moisture content up to saturation of the soil. Beyond this point increased moisture content has comparatively little effect.

3. Temperature changes within the limits commonly met with in practice have no important effect on corrosion efficiency.

4. The depth of burial of pipes has no direct effect on corrosion efficiency provided other conditions remain constant. In practise however, the moisture content, current carried by the pipes, and various other factors which affect corrosion efficiency will vary with depth so that indirectly differences due to depth may be noted.

5. The amount of oxygen present has no appreciable effect on the efficiency of corrosion, in the case of iron immersed in liquid electrolyte.

6. Corrosion efficiency of iron imbedded in earth is always greater in open vessels than in sealed vessels.

7. The amount of oxygen present has a marked effect on the end products of corrosion. If the corrosion is rapid and the supply of oxygen small, there will be a preponderance of magnetic

oxide while if the rate of corrosion is low and the supply of oxygen abundant the ferric oxide will predominate. Owing to the fact that the supply of oxygen around pipes buried in earth is always more or less limited, the character of the oxides formed gives some indication as to the rate of corrosion, and thus indirectly as to the cause of the corrosion, if local conditions are properly considered.

8. There is no material difference in the efficiency of corrosion shown by the various kinds of iron commonly used in the manufacture of underground pipes.

9. The fact that a given chemical tends strongly to inhibit either self corrosion or electrolytic corrosion in liquids is no in-indication that it will materially retard electrolysis of iron imbedded in soils.

10. Pitting of iron imbedded in soils is affected not only by a non-homogeneous condition of the iron or soil, but also by the chemicals contained in the soil.

11. The efficiency of corrosion was found not to be a function of the voltage except in so far as the current density may be affected. Voltages as low as 0.1 and 0.6 volts showed practically the same efficiency of corrosion as 5 to 10 volts or higher.

12. Corrosion tests on a large number of different kinds of soil from widely different sources, with average moisture content and moderate current density, indicate that corrosion efficiencies between 50 and 110 per cent may usually be expected under most practical conditions.

13. The resistance of soils varies throughout a very wide range with variations in moisture content, the resistance of the comparatively dry soil being of the order of several hundred times the resistance of the same soil at about saturation. Above saturation increase in moisture content has but little effect on the resistance of the soil.

14. Because of the great variations in resistance of earth with moisture content voltage surveys should not be made at times when the earth is extremely dry.

15. The resistance of the soils varies greatly with temperature within the ordinary range encountered in practise. In the case of the soils tested the resistance at 18 deg. below zero cent. was over two hundred times as great as at 18 deg. above zero cent. Even at about freezing temperature the resistance will be several times that at summer temperatures. This not only has an important bearing on the magnitude of the electrolysis

trouble that may occur at different seasons, but it also indicates that where practicable voltage surveys should not be made when extremely low temperatures prevail.

16. The experimental results given in this paper have an important bearing on the subject of electrolysis mitigation through the limitation of voltage drop in the negative return. For some years the chief means of preventing trouble from electrolysis in certain foreign countries has been the limitation of the permissible voltage drop between any two points on the return circuit. In some places the limit has been placed on the maximum voltage during peak load, whereas in other cases the average voltage for twenty four hours has been the determining factor. It will be evident that if the total amount of damage which results is proportional to the average current, then the limitation of the average voltage would be more logical than the limitation of the peak load voltage, since in the former case the cost of meeting the voltage limitation in any given case would be proportionate to the danger involved irrespective of the station load factor; whereas if the voltage at peak load is the determining factor, the cost of complying with the requirements depend not only on the danger involved, but on the load factor of the system, and the poorer the load factor, the greater its cost will be. It appears from the data presented in this paper that the rate of damage does not increase as fast as the voltage increases, because of the tendency toward lower corrosion efficiencies at higher current densities. This indicates that, with a given average all-day current, the actual amount of electrolysis that would occur would be less than with a bad load factor than with a good load factor, and hence points to the undesirability of penalizing a high peak of short duration. It would appear very much more logical therefore, in so far as the damage itself is concerned, to make the average all-day voltage the basis of the limitation rather than the voltage at time of peak load.

In conclusion the authors wish to acknowledge their obligation to their colleagues, Mr. O. S. Peters and Dr. H. E. Palmer; to the former for valuable cooperation in the development of the electrolytic method for cleaning anodes which was used throughout this investigation, and also for a large amount of work on the measurement of earth resistances; to the latter for the chemical analyses of soils, and the carrying out of experiments on the effect of oxygen on the end products of corrosion.

OPERATION OF FREQUENCY CHANGERS

BY

N. E. FUNK

Presented under the auspices of the

Electric Lighting Committee

OPERATION OF FREQUENCY CHANGERS

BY N. E. FUNK

ABSTRACT OF PAPER

The objects of this paper are;

1. To analyze the fundamental theory underlying the parallel operation of frequency changers.

2. To consider the various running conditions imposed upon the parallel operation of frequency changers.

3. To apply the theory to the operating conditions in such a manner that it is possible for the operator without technical information, to automatically obtain the correct conditions applying to synchronizing under all possible conditions of load.

4. Development of formulas applying to the phenomena in question

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 26, 1913.

OPERATION OF FREQUENCY CHANGERS

BY N. E. FUNK

The object of this paper is to discuss the general conditions governing parallel operation, the theory, practical operation, and methods of synchronizing two or more frequency changers consisting of two synchronous machines which tie together two systems of different frequency at one or more points. When only one frequency changer is used to connect two systems, all of the difficulties experienced in the parallel operation of frequency changers disappears, as the operation then involves only connecting a synchronous motor to one system and a synchronous generator to the other. The only difficulty in this case being the adjustment of the frequencies of the two systems to permit synchronizing.

Before any definite idea of the method of performing an operation can be grasped, it is necessary to fully understand the underlying principles governing the phenomena in question. These principles must be reduced to their simplest value, which, while affecting the accuracy of the final result still presents it in the most comprehensive manner.

General Conditions

1. Suppose the motors and generators of two frequency-changer sets are in synchronism, and the motors only are connected to the bus. Since these motors are synchronous machines, they will keep both units of each machine in phase. The generator of one set is now connected to the bus and slowly loaded, while the other generator is allowed to run light. If the synchroscope is connected to these generators before any load is on the bus, the indicator will assume a position showing synchronism.

As the load is increased, the synchroscope indicator will slowly move away from the position of synchronism, the angle of variation being roughly proportional to the load. This voltage lag angle is due to the magnetic lag of the armature and mechanical lag of the fields of the loaded machine due to load. If it is necessary to parallel the unloaded machine with the loaded machine, this machine switch must be closed with the synchroscope needle out of synchronism, since it will assume the same lag as the loaded machine when it carries its share of the load.

2. If one of the sets is running unloaded, and the other set is brought from rest to full speed, preparatory to synchronizing, it will be noted after both synchroscopes have been connected that when one synchroscope indicates synchronism, the other one may be at various different positions on the synchroscope face, and vice versa. If the systems are 60-cycle and 25-cycle respectively, there will be twelve different indications of the 25-cycle pointer for synchronous indications on the 60-cycle synchroscope, and five different indications of the 60-cycle pointer for synchronous indications on the 25-cycle synchroscope.

Theory

1. Any alternating-current apparatus containing a current-carrying winding through which magnetic lines are passing, is subject to induction losses. The armature of an alternator is no exception to this general rule. The voltage at the terminals of an alternator carrying load is therefore less than the generated voltage, by the vector difference of the generated voltage and the resistance and inductance losses. Fig. 1 represents a single-phase generator and is self explanatory inasmuch as it is the conventional clock diagram showing the voltage loss in a circuit containing inductance and resistance. In Fig. 1 let E equal the maximum value of the terminal voltage, E_g the maximum value of the generated voltage, and I the maximum value of the load current.

ωL inductive ohms of armature. R resistance of armature. $\cos \theta$ power factor of load current. To make the problem as simple as possible, consider unity power factor. This corresponds to actual conditions, as frequency changers are operated at 100 per cent power factor wherever possible.

Fig. 2 shows the voltage relations in this system. The voltage E lags behind the generated E_g by an angle that is roughly proportional to the inductance of the armature times the load

carried; since the inductance is fairly constant this angle may be assumed to vary with the load. The effect of resistance in Fig. 2 is to reduce the terminal voltage but not to make any great change in the voltage lag angle. The resistance effect will therefore be neglected in the following discussion. If the generator is assumed to be operating as a synchronous motor, the effect will be the same as in Fig. 2 except that E and E_g will now change places since the counter e.m.f. of the motor is less than the bus voltage by the losses in the motor armature. Assume that the frequency-changer set consists of a 60-cycle motor driving a 25-cycle generator. Let K_1 equal the proportionality factor by which the load L may be multiplied to obtain the lag angle of the bus voltage behind the generator voltage, and K, the same factor for the motor. α_1^0 and α^0 are the corresponding lag angles. Assume the set is carrying a given load L. The counter e.m.f.

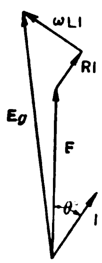


FIG. 1

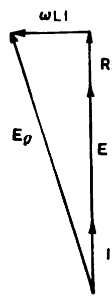


FIG. 2

of the 60-cycle motor will be α^0 behind the position it would assume at this instant if the motor were unloaded. $\alpha^0 = K\,L$. The field poles will be behind the position they would occupy at this instant if the machine were unloaded by $\alpha^0/p/2$ mechanical degrees, where p is the number of poles on the machine. The field poles of the 25-cycle machine are rigidly connected to the 60-cycle machine poles and are therefore the same mechanical degrees behind the position they would assume at this instant if the machine were unloaded. The maximum value of the 25-cycle generated voltage will occur

$$\frac{\alpha^0}{p/2} \times \frac{P_1}{2}$$

electrical degrees after it would occur if the machine were unloaded, p_1 being the poles on the 25-cycle machine. The bus voltage of the 25-cycle generator as in any generator will lag

behind the generated voltage by an angle proportional to the load. $\alpha_1^0 = K_1 L$. The maximum voltage of the 25-cycle bus will occur at an instant later than it would occur if the machine were unloaded by a time angle of

$$\alpha^0 \times \frac{P_1}{P} + \alpha_1^0 = L K \frac{P_1}{P} + L K_1 = L \left(K \frac{P_1}{P} + K_1 \right) = \beta^0$$

and this lag angle will vary with the load. It should be understood that while the above relation is true only for unity power factor, it is a rough indication of what is happening in the armature of the set and is much more apparent than the complicated formula that illustrate actual conditions, which are given at the end of the article.

Having now established the fact that there is a time lag angle between the maximum values of the generated voltage when the machine is carrying load and when unloaded, the next step is to determine what effect this phenomenon will have in paralleling two frequency changer sets. If both sets were unloaded, it would only be necessary to parallel the machines when both 60-and 25-cycle synchroscopes indicate synchronism. Conditions change however, when it becomes necessary to parallel an unloaded set with a loaded set. The generator of the unloaded set will have no lag while the 25-cycle bus voltage of the loaded machine will have a time angle lag of

$$L \left(K \frac{P_1}{P} + K_1 \right) = \beta^0$$

behind the position it would occupy it unloaded at this instant.

If the maximum voltage of the loaded machine is β^0 behind the position it would occupy if unloaded, and the maximum voltage of the unloaded machine coincides with the unloaded position of the loaded machine, then the unloaded machine must be ahead of the loaded machine by an angle β^0. It is necessary to close the 25-cycle switch of the unloaded machine when it is β^0 ahead of bus voltage in phase if it is to assume its share of the load.

If the 25-cycle machine were synchronized first, the indication of the 60-cycle synchroscope would show the motor voltage behind the 60-cycle bus voltage by an angle

$$\left(K_1 \frac{P}{P_1} + K \right) L = \beta^0{}_1$$

This can be easily understood after a moment's thought. For, since the loaded 25-cycle bus voltage is behind the position it assumes at this instant if unloaded and the 25-cycle unloaded machine is in synchronism with it, but has no time to lag in its own armature or the armature of the 60-cycle machine connected to it, the time lag of the loaded machine is reflected in the 60-cycle synchroscope indication of the unloaded machine.

The synchroscope indications will be as shown in the diagrams, Figs. 3, 4, 5 and 6.

LOAD TRANSFERRED FROM 60-CYCLE TO 25-CYCLE BUS

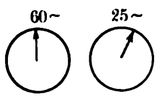


FIG. 3—60-CYCLE MACHINE SYNCHRONIZED FIRST

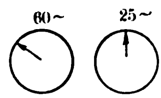


FIG. 4—25-CYCLE MACHINE SYNCHRONIZED FIRST

LOAD TRANSFERRED FROM 25-CYCLE TO 60-CYCLE BUS

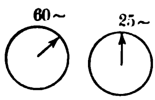


FIG. 5—25-CYCLE MACHINE SYNCHRONIZED FIRST

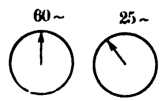


FIG. 6—60-CYCLE MACHINE SYNCHRONIZED FIRST

These four indications are the only indications obtainable when it is correct to put both ends of the set in parallel. Of course, the angles indicated on the synchroscope will vary from zero at no load on the running machine to an angle depending upon the value of the inductance of the armatures of the 60- and 25-cycle machines of the set and the load carried.

VARIATIONS IN SYNCHROSCOPE INDICATIONS

If above phenomena were the only trouble incident to paralleling frequency-changing sets in which the frequency of one machine is not a multiple of the other, there would be nothing more to say about the matter, but as a matter of fact, the most annoying part of the operation to the operator at least, is the fact that there is only one set of poles on the unit at which synchronism occurs at the same instant on both the 60- and 25-cycle synchroscopes. That is, only one indication in twelve on the 60-cycle and one in five on the 25-cycle is the correct one for paralleling.

Consider a 24-pole, 60-cycle machine connected to a 10-pole,

25-cycle machine. Assume that a positive machine pole has come to rest under the middle of one of the phase windings in each machine. This position will indicate synchronism on both synchroscopes. Now, turn the fields until the second 60-cycle positive pole assumes the position that the first pole assumed. The fields will have been turned through

$$\frac{360}{12} = 30$$

mechanical degrees. The 25-cycle machine poles will also have moved 30 mechanical degrees but since the positive poles are

$$\frac{360}{5} = 72$$

mechanical degrees apart, the positive pole will not be near the middle of the winding and therefore will indicate some other than synchronous position on the synchroscope. The following diagram (Fig. 7) indicates the relation these various pole positions bear to one another.

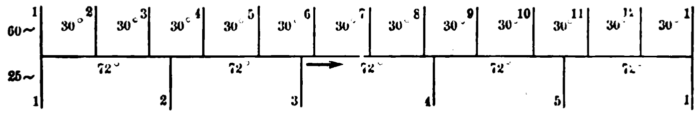


FIG. 7

The vertical lines above the horizontal line represent the middle of the positive poles on the 60-cycle machine and the vertical lines below the horizontal line represent the middle of the positive poles on the 25-cycle machine. Point 1 is the reference point and represents the middle point of an armature winding on one phase of each machine. The arrow indicates the direction in which the machines are supposed to be rotating. If the machines are revolving at the same speed and No. 1 point of both machines coincide, then both synchroscopes would indicate zero, but if No. 1 point of the 60-cycle No. 1 machine coincided with Point No. 6 60-cycle of No. 2 machine, then the nearest pole to No. 1, 25-cycle of No. 1 machine would be No. 3 pole of No. 2 machine which is $5 \times 30 - 2 \times 72 = 6$ mechanical degrees behind synchronous indication. If No. 2 machine is speeded up slightly then the 60-cycle needle will revolve five times before both No. 1 poles coincide, and the 25-cycle needle will revolve twice.

It is easily seen that at no point will be maximum value of the 25-cycle voltage occur simultaneously with the maximum value of the 60-cycle voltage except at zero or 360 which are one and the same point. To plot these indications on the face of the synchroscope it is necessary to construct a table showing the mechanical and then the electrical degree variations; considering first, synchronous indications on the 60-cycle synchroscope and then on the 25-cycle synchroscope. *O*, will be used to indicate synchronism, + or − indicates that the angle in question is clockwise or counter-clockwise from synchronous position. The tables are given below and in connection with the diagram will be readily understood when the first two steps are explained. Consider pole No. 1, 60-cycle. When this pole is under the middle of one phase of the armature winding the synchroscope indicates zero, the 25-cycle synchroscope will also show *O*, since No. 1 pole is supposed to be under the middle of one phase of the 25-cycle armature winding. Suppose that instead of No. 1 pole 60-cycle, No. 2 pole, 60-cycle was under the middle of the same phase winding. No. 1 pole, 25-cycle would then be 30 mechanical degrees behind the middle of the phase winding of the 25-cycle armature and be approaching it, therefore, it would be behind in phase relation or on the *slow* side of the synchroscope. Similarly No. 3 pole, 60-cycle would be at its maximum position when No. 2 pole, 25-cycle had passed the middle position of the reference line on the armature and therefore would indicate a leading phase position on the synchroscope; *i.e.*, the pointer, would be on the *fast* side of the synchroscope. The indications on the 60-cycle synchroscope are worked out in the same manner. (See Table II and Fig. 7).

The application of the data at hand is the next point to which to turn our attention. Suppose the set is being synchronized and the speed is slightly above synchronism. When the 60-cycle synchroscope shows synchronism, the 25-cycle is 90 deg. on the left hand side of the synchroscope face. Look in the table, and opposite—90 is found pole No. 4 on the 60-cycle machine. Since the machine is running fast this means that by the third time the 60-cycle pointer moves around the dial, the 25-cycle pointer will have reached synchronous position. If the machine were running slow, it would be necessary for the 60-cycle pointer to revolve 9 times before both synchroscopes showed synchronism. Instead of using the tables, it is much more convenient to construct a small indicator similar to a

synchroscope face and locate the values on this. As these markings will vary with the method of synchronizing, as will be explained later, the general methods of starting will be taken up and the use of the calculator illustrated for each case.

TABLE I

Pole No.	Syn. indications 60 ~	Syn. indications 25 ~ mech.	Syn. indications 25 ~ elec.	Pole No.	Syn. indications 60 ~	Syn. indications 25 ~ mech.	Syn. indications 25 ~ elec.
1	0	0	0	7	0	−36	−180
2	0	−30	−150	8	0	+ 6	+ 30
3	0	+12	+ 60	9	0	−24	−120
4	0	−18	− 90	10	0	+18	+ 90
5	0	+24	+120	11	0	−12	− 60
6	0	− 6	− 30	12	0	+30	+150

TABLE II

Pole No.	Syn. indications 25 ~	Syn. indications 60 ~ mech.	Syn. indications 60 ~ elec.
1	0	0	0
2	0	−12	−144
3	0	+ 6	+ 72
4	0	− 6	− 72
5	0	+12	+144

Methods of Starting

1. By induction motor or d.c. motor mounted on shaft of frequency changer set.

2. By using one of the machines of the frequency set as an induction motor.

First Method—Induction Starting Motor. This motor is usually of the wound rotor type. Suppose load is being transferred from the 60-cycle to the 25-cycle bus. The process of starting is as follows. The induction motor is put on the bus with all the resistances in the rotor, and as the machine comes slowly up to speed this resistance is cut out. The fields of both synchronous machines are put on and the 60-cycle field is adjusted to give 60-cycle bus voltage. It is impossible to so adjust the rotor resistance that exact synchronizing speed is obtained since changes in resistance due to heating will change

the slip and the steps in the resistance would have to be very large in number with small values between each step. Proper speed may be obtained by using the resistance step that gives the nearest value to synchronous speed and obtaining the finer adjustment by varying the 25-cycle field. This changes the iron loss in the 25-cycle armature and thus the load and slip on the induction starting motor. The 60-cycle machine will be synchronized first and then the 25-cycle machine will be put on, as it is more logical to connect the motor to the source of supply before connecting the generator to the load. It is now necessary to construct our synchronizing indicators before we can intelligently synchronize our machines.

These synchronizing indicators consist of small cardboard representations of the synchroscope face with a revolving disk attached. On this disk are shown the synchroscope pointer and the positions the pointer will assume at other than synchronous indications. In Fig. 8 the outer circle represents the stationary disk of the indicator while the inner circle is the revolving disk.

The outside circle, Fig. 8, is divided into 36 10-deg. spacings and these same divisions are marked on the 25-cycle synchroscope face. The inner movable disk is divided into 12 divisions corresponding to each position that the 25-cycle pointer assumes when the 60-cycle pointer indicates synchronism. The 10-deg. spacings are numbered arbitrarily and no numbers are used higher than 9 to save confusion when standing at a distance from the synchroscope. The 12 spaces on the moving disk are laid off as follows. (See Table I and Fig. 7).

When both 25-cycle and 60-cycle machines are in synchronism, the indication is as shown by the black synchroscope dial hand. When 60-cycle pole No. 2 is at No. 1 pole position, the 25-cycle pointer will have to move 150 degrees while the 60-cycle pointer moves around the dial once if the machine is running slightly above synchronism; therefore, the position marked 1 on the 25-cycle synchroscope means that the 60-cycle synchroscope pointer must make one more complete revolution before both will be in synchronism. If the machine were running slightly below synchronism, the correct pole for synchronizing would be moving farther away from the synchronizing position and it would be necessary for the machine to make a complete revolution relative to the running machine; therefore, the 60-cycle synchroscope pointer would be compelled to revolve 11 times before both pointers would indicate synchronism simultaneously.

In a similar manner, when No. 3 pole, 60-cycle is at No. 1 pole position, No. 2 pole 25-cycle is 60 degrees ahead in phase, and it is necessary for the 60-cycle synchroscope pointer to revolve 2 times fast, or 10 times slow before both are in synchronism. The 60-degree mark is therefore labelled 2 fast or 10 slow. The small arrows indicating the direction in which the needle is rotating. In this manner, all the other points are labelled.

In the first part of this paper, the lag angle due to load was explained. On the top of the stationary dial to the right and left are laid off the markings indicating the position of the pointer for various loads. The method of obtaining these load markings is given at the end of this paper.

To continue with synchronizing the machines. Suppose the amount of load carried by the running machines is X (See Figs. 8 and 3). Both synchroscopes are revolving slowly in the fast direction. Set the pointer to X, this revolves all the indications for other than synchronous positions as it should, since they are affected by load as well as the synchronous position of the pointer. Suppose the 25-cycle pointer lies between 8 and 9 (y) when the 60-cycle pointer shows synchronism (by inspection it will be seen that is the point 10◀━▶2 will assume when the inner dial is shifted). This means that the second time the 60-cycle pointer rotates around the dial face and comes to synchronism is the proper time to close the 60-cycle switch. When this has occurred the 25-cycle pointer will occupy the position indicated by X. The 25-cycle field is then adjusted and after the starting motor has been taken off, the 25-cycle switch is closed, with the 25-cycle pointer about 22 deg. ahead of the bus in phase. The machine will assume its correct share of the load.

If instead of rotating fast, the synchroscopes had been rotating slowly, then the 60-cycle pointer would have rotated 10 times before the 25-cycle pointer would have reached X when the 60-cycle pointer indicated synchronism.

If the load was being transferred from the 25-cycle bus to the 60-cycle bus and the machines were synchronized in the same sequence as before, the point marked X_1 would be the proper indication of the 25-cycle pointer when the 60-cycle switch should be closed (see Figs. 6 and 8). The last method should only be used when there is some reason for not using the 25-cycle switch for synchronizing purposes.

Suppose that all the conditions of starting are the same as stated for the above except that load is to be transferred from

the 25-cycle to the 60-cycle bus and that the 25-cycle machine, being the motor, is to be synchronized first. A new synchronizing indicator is necessary, and will show on the 60-cycle synchroscope the number of times that the 25-cycle pointer must revolve before the 25- and 60-cycle synchroscopes will indicate synchronism simultaneously. This indicator is constructed the same as Fig. 8, except that Table II and Fig. 7 are used. The load lag angle will be greater on the 60-cycle synchroscope than on the 25-cycle. Suppose for a given load the electrical degrees displacement are 10 in both armatures, the lag on the 25-cycle synchroscope is

$$10 \times \frac{5}{12} + 10 = 14.16 \text{ deg.}$$

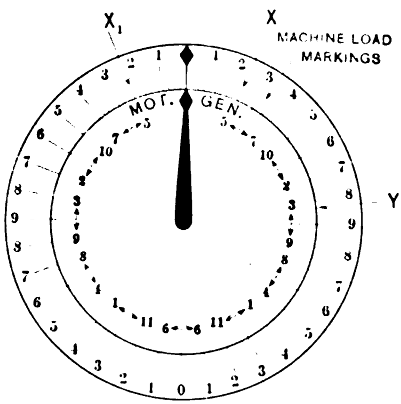


FIG. 8

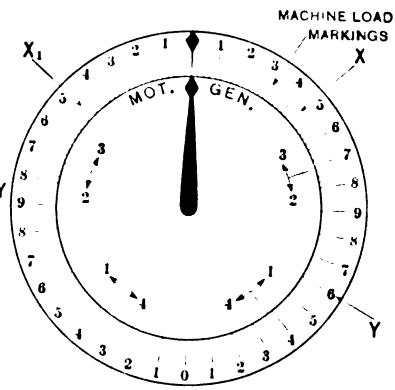


FIG. 9

and on the 60-cycle synchroscope is

$$10 \times \frac{12}{5} + 10 = 34 \text{ deg.}$$

The operation of synchronizing is the same as for Fig. 8, except 25-cycle is substituted where 60-cycle is used, and vice versa.

The only difference in operation where a d-c. starting motor is used is that it is possible to obtain correct synchronous speed by adjusting the d-c. motor field and it is therefore unnecessary to use the synchronous generator field as a speed adjusting medium.

Second Method. Assume the 60-cycle machine acting as a motor and load being transferred from the 60-cycle to the 25-

cycle bus. The 60-cycle machine is started at reduced voltage by an auto-starter or some other means. When the machine has reached full speed the field is put on both units. It is now necessary to construct a synchronism indicator since only one synchroscope will be available for synchronizing. The 25-cycle synchroscope will be laid off as before, the only difference being that the markings now indicate the number of times the 25-cycle pointer must pass synchronous indication before the proper synchronizing point is reached. This may be constructed from table I and Fig. 7, or from Fig. 8 by multiplying the numbers on the dial by 5/12 and discarding the remainder. The closing of the 60-cycle motor field locks the set in synchronism on the 60-cycle side. Suppose the 25-cycle pointer is at y, this cor-

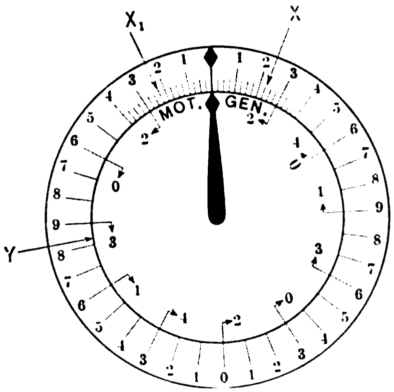


FIG. 10

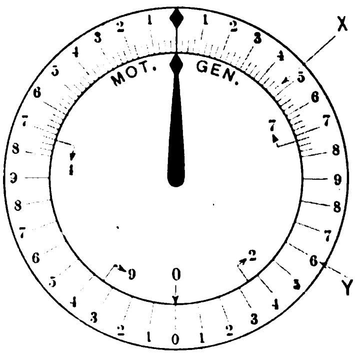


FIG. 11

responds to 1 on the revolving dial when the pointer has been placed at X. The field of the 60-cycle motor is now taken off and the 25-cycle pointer will begin to revolve in the slow direction. When it has passed synchronous position once and reached the point 0, the 60-cycle field is again closed, which locks the motor in synchronism. The 25-cycle pointer will now stand at X.

The 60-cycle machine is thrown from starting to running voltage taps and the 25-cycle machine switch is closed. If all conditions were the same ,but the load were being transferred from the 25-cycle bus, the indicator pointer would be set at X_1, but all the operations would be the same, assuming the 60-cycle machine was the one equipped with the starting device. If the 25-cycle machine was equipped with the starting devise, the operation would be the same as before, assuming that the load transferred

from 25-cycle to 60-cycle bus, 25-cycle inserted for 60-cycle and vice versa. The synchronism indicator shown in Fig. 11 would then be used, showing indications on the 60-cycle synchroscope of the number of times the 60-cycle needle must pass synchronous indication before the proper time for synchronizing. Fig. 11 is obtained from Fig. 9 by multiplying by 12/5 and dropping the remainder, or from Fig. 7 and Table II.

All instances in the above cases have depended on the assumption that there was the same percentage inductive loss in the armatures of both sets.

A difference in size can be accounted for on the indicator as follows. If the running machine is one half size, take twice the load it is carrying on the indicator, assuming that the indicator is calculated, for the largest machine, or the load indications may be left off the indicator and a table made showing the lag for each machine in terms of the 10 degrees spacing, (see Tables III and IV). These tables show No. 1 small, No. 2 next, and No. 3 the largest machine. The values were arbitrarily set down and do not indicate actual values.

TABLE III

25 ~

Load kw.	Machine No. 1	Machine No. 2	Machine No. 3
500	0.8	0.4	0.2
1,000	1.6	0.8	0.4
1,500	2.3	1.1	0.6
2,000	2.9	1.5	0.8

TABLE IV

60 ~

Load kw.	Machine No. 1	Machine No. 2	Machine No. 3
500	1.9	0.9	0.5
1,000	3.8	1.9	0.9
1,500	5.5	2.7	1.4
2,000	6.9	3.5	1.9

Effect of Different Percentages of Armature Inductance on Parallel Operation of Frequency Changers

If the machines have different percentages of inductive loss then when all are in parallel, they will not share the load equally. This may be overcome by arranging one of the armatures of each

set so that it may be revolved, and by shifting the various armatures it is possible to make the machines share the loads equally at some one point, but in this event the machines will not share the load satisfactorily if load is transferred in the reverse dierction. For example, consider the inductance of one machine such that the generator and motor voltages have a time lag of 10 mechanical degrees at full load over the no load value, the other machine 15 mechanical degrees. If these machines are in parallel, the lag angle must be the same in both, and if we consider the angle proportional to the load, No. 2 machine will only carry 66 per cent of full load when No. 1 is fully loaded. To enable the machines to divide the load evenly it would be necessary to shift No. 2 motor armature ahead, or No. 2 generator armature back, considering direction of field rotation as forward movement. If the direction of power transfer was now interchanged the machines would not share the loads as well as before

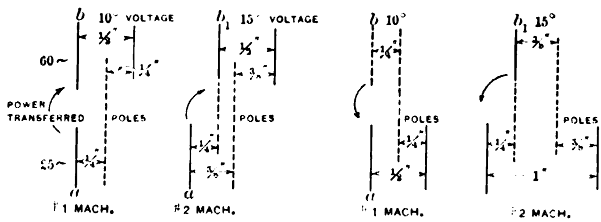


FIG. 12

the armatures were moved. Fig. 12, while not mathematically correct, shows clearly why this is so.

In this figure, a and b are the mid-points of the armature windings of the machine with a 10-degree lag angle represented by $\frac{1}{4}$ in., and a_1 and b_1 are the mid-points of the armature of the machine with a 15-degree lag angle represented by $\frac{3}{8}$ in. Suppose power is transferred from 25-cycle to 60-cycle bus. The lag in the 25-cycle armature is $\frac{1}{4}$ in. (this is the mid-point of the poles). The lag in the generator armature is $\frac{1}{4}$ in., thus making the amount the 60-cycle voltage lags $\frac{1}{2}$ in. In machine No. 2, the armature is moved ahead $\frac{1}{4}$ in. and the lag of the motor armature is $\frac{3}{8}$ in. (this is the mid-pole position). The generator armature lag is $\frac{3}{8}$ in. making a total of $\frac{1}{2}$ in., and since these two angles are the same, the machines will each take their share of the load. If the direction of power transfer is reversed, No. 1 machine still shows a lag of $\frac{1}{2}$ in. but No. 2 is $\frac{3}{8}$ in. on the

motor end, $\frac{3}{8}$ in. on the generator end plus $\frac{1}{4}$ in. that the armature has been moved, making 1 in. or twice the lag of No. 1 machine, in consequence No. 1 will carry 140 per cent load and No. 2 will carry 60 per cent load, assuming machines to be of equal capacity and the total load equal to the combined capacity of both machines.

$$X = \text{No. 1 machine load}$$

$$Y = \text{No. 2 \quad `` \quad ``}$$

$$\frac{X\,\frac{1}{2}}{100} = \frac{\frac{3}{4}\,Y}{100} + \frac{1}{4}$$

$$X + Y = 200$$

$$\frac{1}{2}\,\frac{(200 - Y)}{100} = \frac{\frac{3}{4}\,Y}{100} + \frac{1}{4} \times \frac{100}{100} = \frac{\frac{3}{4}\,Y + 25}{100}$$

$$100 - \frac{Y}{2} = \frac{3}{4}\,Y + 25$$

$$75 = \frac{5}{4}\,Y$$

$$Y = \frac{4}{5} \times 75 = 60$$

$$X = 200 - 60 = 140$$

This shows that great care must be taken in writing the specifications for purchasing frequency changers, that are to transfer load alternately from one frequency to another, and still greater care in designing them. For while it is possible to arrange the set so that the load will be properly divided at some specific point when transferring load in a given direction, no matter if the per cent inductance varies considerably, the sets will not operate satisfactorily when the direction of load transfer is reversed. This statement of course, applies only to the case where two sets are operating in parallel in the same station, as where two systems are tied together by two frequency changer sets located in different stations, the line inductance determines

to a great extent the proper division of the load. With only one set connecting two systems, however, the phase angle of the frequency changer set has nothing to do with the amount of load it carries. The amount of load being determined in this case by the governor settings of the prime movers of the respective systems.

Formulas for Phase Angle Variations of Frequency Changer Units

$\omega L I$ = Inductive voltage loss in motor armature, full load
$r I$ = Resistance “ “ “ “ “ “
I = Load current of “ “ “ “
E = Bus voltage, motor end.
θ = Power factor motor end
α = Lag angle, “ “
f = Motor frequency.
f' = Generator “
α' = Lag angle generator end.
θ' = Power factor “ “
E' = Bus voltage “ “
I' = Load current “ “
$r' I'$ = Resistance voltage loss generator armature full load.
$\omega' L' I'$ = Inductive voltage loss generator armature full load.

$$\mathrm{L} = \frac{\omega L I}{E}$$

$$R = \frac{r I}{E}$$

$$\mathrm{L}' = \frac{\omega' L' I'}{E'}$$

$$R' = \frac{r' I'}{E'}$$

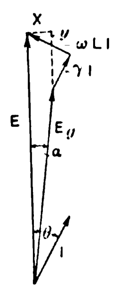


Fig. 13

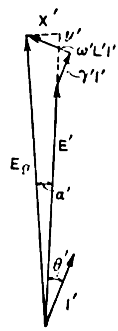


Fig. 14

α_t = the total phase angle generator.

$$\cos \alpha = \frac{E - Y}{\sqrt{(E - Y)^2 + X^2}}$$

$$Y = r\,I\cos\theta + \omega\,L\,I\sin\theta$$

$$X = \omega\,L\,I\cos\theta - r\,I\sin\theta$$

$$\frac{r\,I}{E} = R$$

$$\frac{\omega\,L\,I}{E} = \mathbf{L}$$

Substituting,

$$\cos\alpha = \frac{1 - R\cos\theta - \mathbf{L}\sin\theta}{\sqrt{1 - 2\,(R\cos\theta + \mathbf{L}\sin\theta) + R^2 + \mathbf{L}^2}}$$

$$\cos\alpha' = \frac{E' + Y'}{\sqrt{(E' + Y')^2 + X'^2}}$$

$$Y' = r'\,I'\cos\theta' + \omega'\,L'\,I'\sin\theta'$$

$$X' = \omega'\,L'\cos\theta' - r'\,I'\sin\theta'$$

$$\frac{\omega'\,L'\,I'}{E'} = \mathbf{L}'$$

$$\frac{r'\,I'}{E'} = R'$$

Substituting,

$$\cos\alpha' = \frac{1 + R'\cos\theta' + \mathbf{L}'\sin\theta'}{\sqrt{1 + 2\,(R'\cos\theta' + \mathbf{L}'\sin\theta') + R'^2 + \mathbf{L}'^2}}$$

$$\alpha_{\mathrm{T}} = \alpha\,\frac{f'}{f} + \alpha'$$

$$\alpha = \cos^{-1}\frac{1 - R\cos\theta - \mathbf{L}\sin\theta}{\sqrt{1 - 2\,(R\cos\theta + \mathbf{L}\sin\theta) + R^2 + \mathbf{L}^2}}$$

$$\alpha' = \cos^{-1}\frac{1 + R'\cos\theta' + \mathbf{L}'\sin\theta'}{\sqrt{1 + 2\,(R'\cos\theta' + \mathbf{L}'\sin\theta') + R'^2 + \mathbf{L}'^2}}$$

$$\alpha_{\mathrm{T}} = \frac{f'}{f}\cos^{-1}\frac{1 - R\cos\theta - \mathbf{L}\sin\theta}{\sqrt{1 - 2(R\cos\theta + \mathbf{L}\sin\theta) + R^2 + \mathbf{L}^2}}$$

$$+ \cos^{-1}\frac{1 + R'\cos\theta' + \mathbf{L}'\sin\theta'}{\sqrt{1 + 2\,(R'\cos\theta' + \mathbf{L}'\sin\theta') + R'^2 + \mathbf{L}'^2}} \qquad (1)$$

It is usual to operate frequency changer sets at unity power factor. Therefore

$$\cos\theta = \cos\theta' = 1$$

$$\alpha_T = \frac{f'}{f}\cos^{-1}\frac{I - R}{\sqrt{1 - 2R + R^2 + \mathbf{L}^2}} + \cos^{-1}\frac{I + R'}{\sqrt{1 + 2R' + R'^2 + \mathbf{L}'^2}} \qquad (2)$$

The resistance loss at unity power factor has its greatest effect in varying the voltage but only a small effect in varying the lag angle, let us therefore assume that the resistance is zero.

$$R = R' = 0$$

$$\alpha_T = \frac{f'}{f}\cos^{-1}\frac{1}{\sqrt{1 + \mathbf{L}^2}} + \cos^{-1}\frac{1}{\sqrt{1 + \mathbf{L}'^2}} \qquad (3)$$

Assuming that the angles are small, we can see from Fig. 15 that they are proportional to L and L' which are proportional to the loads as we assumed in the beginning of this article.

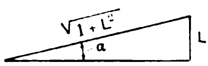


FIG. 15

$$\therefore \alpha_T \propto \text{load}$$

Method of Obtaining Load Readings

It is possible if the constants of the machines are known to obtain the markings on the synchronizing indicators by calculating from formula (1) or fairly accurate results may be obtained from (2) or (3), but the best and most practical way is to run one machine loaded and another one with only the motor connected. The generator synchroscope is then put on and the indications of the pointer are noted for various loads on the running machine. These readings may be plotted on the indicator or in a table as shown earlier in this paper. There are many more interesting points in the operation of frequency changers but the object of this article was to deal only with the synchronizing of these machines.

ELECTRICAL REQUIREMENTS OF CERTAIN MACHINES IN THE RUBBER INDUSTRY

BY

C. A. KELSEY

Presented under the auspices of the

Industrial Power Committee

ELECTRICAL REQUIREMENTS OF CERTAIN MACHINES IN THE RUBBER INDUSTRY

BY C. A. KELSEY

ABSTRACT OF PAPER

The paper outlines the principal operations carried on in a rubber factory and gives some figures on the corresponding power requirements.

The crude rubber as it comes from the forest or plantation must be cleaned, thoroughly kneaded, and mixed with various ingredients to form the final compound. Rubber has a great capacity for absorption of power and is materially benefited thereby. Electrical power can be advantageously used in the working up of rubber, particularly in rolling the compound into sheets, where adjustable speed operation is productive of economies.

The author concludes with a comparison of methods for obtaining adjustable speed operation and points out the desirable features which should be embodied in the control.

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 25, 1913.

(*Subject to final revision for the Transatcions.*)

ELECTRICAL REQUIREMENTS OF CERTAIN MACHINES IN THE RUBBER INDUSTRY

BY C. A. KELSEY

This paper is intended to outline briefly the power requirements of some of the principal machines which work up crude rubber and render it suitable for the manufacture of various articles.

The principal source of rubber is the wild trees of Brazil, although cultivated rubber in increasing quantities is now produced in East India, Ceylon, Malayan Peninsula and Southern Mexico. The former reaches the factory in the form of balls or biscuits about a foot in diameter. Cultivated rubber is universally washed and sheeted at the plantation and is shipped in the form of cakes of folded sheets.

Washing. After the biscuits have been cut into chunks and softened in a bath of warm water, they are fed into a cracker or rough washing mill. This mill consists of two or three rolls between which the rubber passes, is torn apart and rolled out into a rough sheet. Water flowing through the rubber in its passage through the rolls washes out part of the entrapped dirt.

These mills run at a constant speed of 20 to 25 rev. per min. The load is very irregular and depends upon the feeding of the mill. A three-roll washer with continuous feeding requires an average of 25 to 35 h.p., with power peaks of 100 h.p.

The rough sheet is then passed through a single set of rolls where it is further washed and rolled out into a sheet or " crepe."

These mills run at a constant speed or about 25 rev. per min. The load is fairly uniform as the rubber is already in the form of a rough sheet. The power required averages 20 to 25 h.p. and

occasionally runs up to 50 h.p. when the sheet is introduced between the rolls after being doubled.

After the crepe has been dried either in a drying room where it is suspended from the ceiling or placed in a vacuum drier, it is ready to be masticated and mixed with the suitable ingredients to form various compounds.

Masticating. The dried crepe must be worked or masticated into a homogeneous and plastic state before the ingredients are added. This is most economically done in a shorter mill than a mixing mill. The power required at the beginning of the process is greater than at the end and runs up to high value as the rubber is cut free from the roll and doubled back in again. From tests on a 50-in. (1.27-m.) face mill the average power was 37 h.p. and the maximum 74 h.p., while a 60-in. (1.52-m.) face mill required an average power of 90 h.p. and a maximum of 140 h.p. power.

Mixing. Pure rubber is never used in the manufacture of rubber articles without first adding to it some other substance. Different materials are employed depending upon the use and desired characteristics of the rubber product. Some materials increase the elasticity, some impart hardness and toughness and some act as mechanical fillers to cheapen the product without materially affecting the desired characteristics.

Where the rubber is masticated in the mixing mill, the predetermined weight of the various substances are added in a powdered or liquid state only after the masticated rubber has been thoroughly worked and warmed. As the ingredients impart different degrees of hardness and toughness to the final product so will the power to drive the mill vary.

The speed of the rolls ranges from 20 to 25 rev. per min. A 40-in. (1-m.) face mill requires about 20 h.p. average and 40 h.p. maximum on relatively soft compound and 25 h.p. average and 55 h.p. maximum on hard compound while a 60-in. (1.5-m.) face mill requires 55 h.p. average and 120 h.p. maximum on medium compound.

Refining. In some installations the compound after leaving the mixing mill is passed through machines that strain it and reduce it to a very thin sheet. The strainers are in principle like a meat grinder. A feed screw revolving inside a water jacketed cylinder forces the compound through a fine mesh screen which is backed up by a perforated plate. This removes all solid foreign objects which ordinarily find their way into the

material. The compound becomes heated more or less as it passes through the strainer and the final temperature must be kept below a given value. The heating varies with the compound and the initial temperature. An efficient means of maintaining maximum output is to vary the speed. This therefore requires an adjustable speed motor. A two to one speed range is sufficient The power required is 25 h.p. over the whole range. The harder compounds, requiring high torque are run at the slow speeds and the soft compounds requiring less torque are run at the high speeds.

After passing through the strainers the compound is passed through a refiner which is a small mill whose rolls are held very close together. The compound is run through at a thickness of approximately three mils, being passed through several times and finally scraped off the roll as it comes through. It is then bundled up and is ready for the warming mill.

The mills are run at constant speed and uniform load. The power required does not exceed 25 h.p.

Warming. Although the compound is warmed in the mixing mills, it cannot always be used at once in the calenders and, moreover, it is beneficial to the compound to let it season before calendering. Warming mills are therefore essential to warm the compound when it finally comes to the calenders. These mills are identical with the mixing rolls excepting they are equipped with steam heated rolls. The power required is slightly less than for the mixing rolls.

Tubing. When the article to be produced is tubular or ring shaped the compound is forced through tubes. This machine is similar to a strainer excepting that instead of a screen and perforated plate the machine is fitted with a disk which delivers the compound in the form of a tube.

The speed and power requirements approximate those of a strainer.

Calendering. Practically all rubber compounds with the exception of those run through tubes and for the manufacture of molded articles are sheeted in a calender.

This machine has a series of rolls two or four in number arranged one over the other between which the compound is passed to form a sheet. The surface of the rolls is finished smooth and the space between the rolls is adjustable to a very fine degree. The rolls are fitted with steam and water connection to heat or cool the compound as required.

The power required to drive a calender varies over a wide range depending on the character of the compound, thickness, width and speed. The speed is limited to that at which the compound can be run without blistering or the forming of a rough surface. When the calender is started up with cold rolls the permissible speed is higher than after the cooling rolls become heated. As these rolls become heated, it is necessary, in order to obtain the desired surface of the sheet, to reduce the speed. A fine speed graduation is therefore necessary to maintain a maximum output. The torque required depends upon the thickness and material and there are so many combinations possible together with the speed requirements that it is difficult to formulate any rule to determine the power. The motor must be large enough to meet the extreme conditions.

From a number of tests made it is found that an 18-in. (45.6-cm.) diameter, 40-in. (1-m.) face, three-roll calender running at a surface speed of 37 ft. (11.2 m.) per minute, requires an average of 20 h.p. A 24-in. (60-cm.) diameter, 48-in. (1.2-m.) face three-roll calender running at a surface speed of 35 ft. (10.6 m.) per minute requires an average of 35 h.p. and a 22-in. (55.8–cm.) diameter, 65-in. (1.64-m.) face, three-roll calendar running at a surface speed of 36 feet. (10.9 m.) per minute requires an average of 45 h.p.

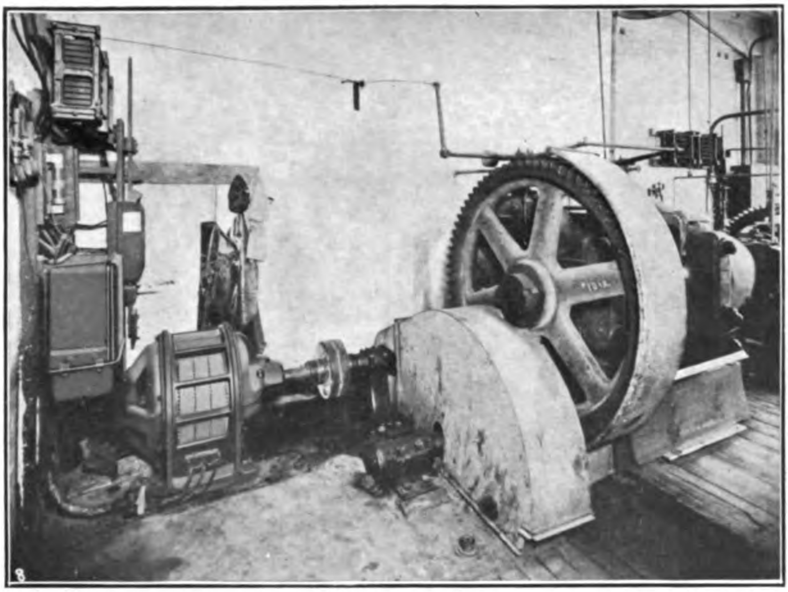
Some compounds that are run through the calender in successive layers which build up to ½ inch (1.27 cm.) or even ¾ in. (1.9 cm.) must be run at approximately 20 ft. (6 m.) per minute while for "friction" work the speed of the driven roll may be 80 ft. (24.3 m.) per minute. The thick sheets will require slightly greater torque than the average thickness while the torque for so-called "friction" work is considerably less.

The term frictioning is applied to that process performed by a calender in forcing a soft rubber compound into the meshes of cotton fabric. It is preliminary to the skimming or coating of the fabric. The rubber compound is very soft and plastic and is rubbed in by the action of the driven roll which travels at a faster speed than the roll carrying the fabric.

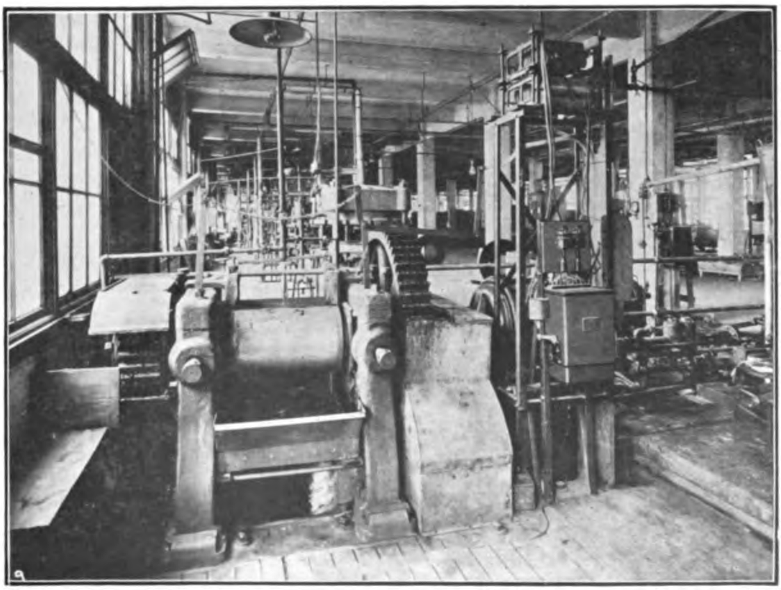
As the compound and fabric are fed through in a continuous sheet the power required for a given material, thickness and width is quite uniform.

Motor Characteristics

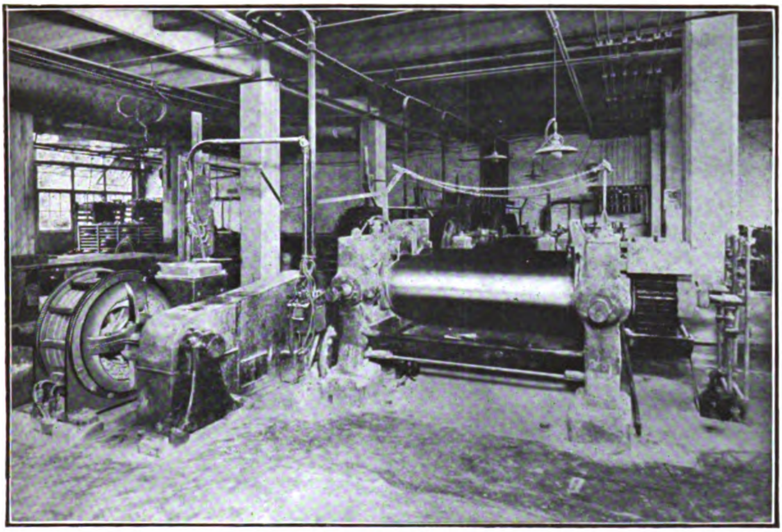
In considering the power and speed requirements of the different machines, it is seen that the mills for working up the rubber



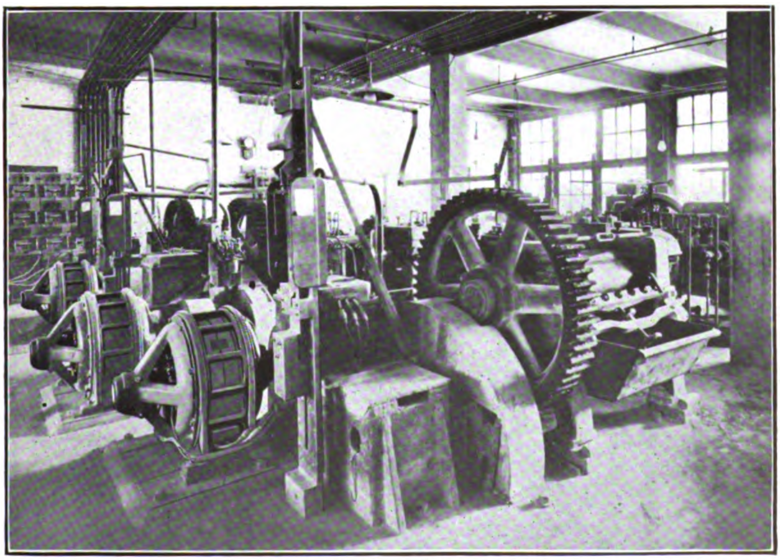
THREE ROLL WASHER [KELSEY]



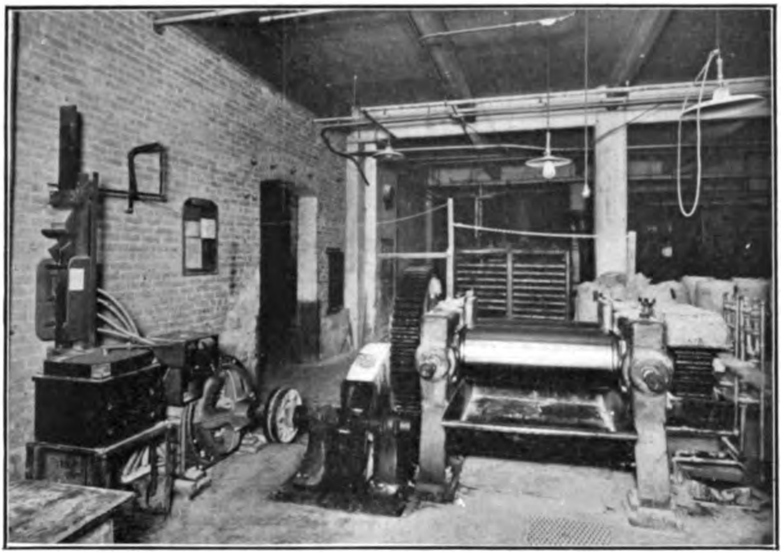
SHEETER [KELSEY]



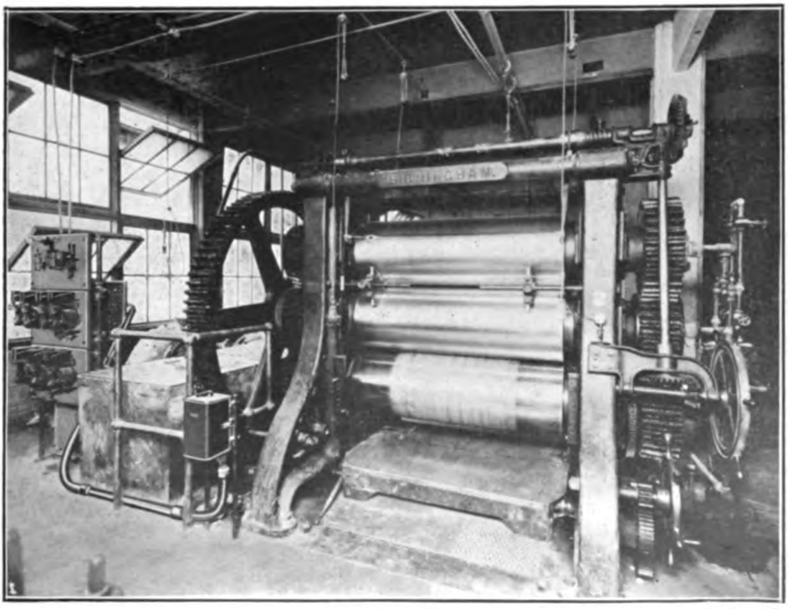
MIXING MILL [KELSEY]



REFINING MILL [KELSEY]



WARMING MILL [KELSEY]



CALENDER [KELSEY]

and mixing it to form the various compounds, call for extreme overloads but of short duration. By grouping these mills and driving by a single motor the load peaks can be reduced. Instead of the maximum values being 200 per cent of the average, it has been determined that this can be reduced to 150 per cent by driving with one motor a group of six mills used for masticating, mixing and warming.

Where individual drive is used, alternating-current polyphase squirrel cage motors are best suited to carry the high load peaks. By grouping the mills, a motor of a smaller capacity than the aggregate of the individual motors can be employed. Moreover, synchronous motors can then be installed and assist in correcting the power factor of the general power load. The mills are generally equipped with jaw clutches which can be open or closed while the shaft is running. The synchronous motor can thus be disconnected from the mills at starting. The selection of squirrel cage or wound rotor induction motor depends upon the local starting restrictions, as the squirrel cage motor will easily bring the shaft up to speed even with all mills connected.

Direct-current motors are sometimes used when this is the power available but they are more expensive and not so well suited to the load conditions.

The calenders, as mentioned, require close speed control over a range of four to one. This can best be accomplished by a direct-current motor, which is the general practise. A number of schemes have been employed to accomplish this. Among them might be mentioned the multi-voltage and adjustable voltage methods.

The motor is excited at constant field strength and the armature supplied with a variable voltage. This variable voltage can be produced by a series of different voltage generators or by a rotary compensator or booster set.

A modification of the preceding is a three-wire, two-voltage source of armature supply combined with adjustable speed by field control. The first mentioned methods produce a wide speed range but are expensive because of the number of machines required for each calender. The second method produces a less speed range but is less expensive, particularly where a large number of calenders are installed.

With the more recent general application of commutating poles to direct current motors a greater speed range is permissible with constant armature voltage and varying field strengths.

This last mentioned method results in the simplest equipment

as a whole. The motor must be larger but is therefore more substantial, while the control can be made extremely simple, or it can be made entirely automatic, thus calling for a minimum of attention and care from the operator.

The tubers also require a direct-current motor and the last mentioned method of speed control is particularly adapted to these machines.

As the power to drive the mills is by far the greatest portion of the total power, alternating current will generally be selected. This therefore requires a motor-generator set or synchronous converter to deliver direct current to the calenders and tubers. These machines can be used to correct the power factor of the general power circuit.

Motor Control

As the motors to drive the mills are run at constant speed, starting devices are only required. A speed controlling device must however, be furnished with the motors driving the tubers and calenders. The former machines are simple in operation and a controller for hand operation which combines starting and speed adjustment is sufficient. The calenders however, require closer attention and must be capable of starting and stopping by the simplest means on the part of the operator. This is best met by a control which enables the operator to bring the calender up to speed by moving the controller handle around to obtain the desired speed. Automatic acceleration should be provided to limit the current input while the controller handle is being moved around. It should then be possible to shut the calender down by pushing a button located on the calender. The speed of the calender should be retarded by dynamic braking of the motor. This is to provide a safety feature in respect to the operator in case his hand should be caught between the rolls. Also, it is desirable to stop quickly to save material otherwise wasted by the coasting of the motor. It should then be possible to bring the calender up to the same speed as before by pushing a button on the calender. Means should be provided for reversing the direction of rotation of the motor to assist in manipulating the calender and also in case anything should be caught between the rolls and it becomes necessary to back it out. The control should also include overload and low voltage release features and be immune from damage to itself or the motor in case the operator fails to close or open the proper switches.

CONVERTING SUBSTATIONS IN BASEMENTS AND SUB-BASEMENTS

BY

B. G. JAMIESON

Presented under the auspices of the

Power Station Committee

CONVERTING SUBSTATIONS IN BASEMENTS AND SUB-BASEMENTS

BY B. G. JAMIESON

Abstract of Paper

This paper treats principally of methods of overcoming the difficulties attendant upon the installation of synchronous converter and battery substations in the basements of large office buildings in the down-town district of a large city. The development covers a period of fifteen years during which time the capacity of the units has been increased as many fold. The combined capacity of such substations is 42,000 kw., serving 0.81 sq. mi. (2.1 sq. km.) of area in which are many high commercial buildings with a connected load of 1,940,000 lamps (50-watt equivalent).

This type of substation is divided into two classes: I—the basement type, referring to those located directly below street level, and II—the sub-basement type, referring to those located in the first or second sub-basement.

Description and illustration of a typical machinery intake for a Class II substation are given, also methods and difficulties of bringing in apparatus.

The air supply for the apparatus as compared with a substation above grade is next considered. A special air cleaning device is described. Description and illustration of a supply and exhaust system for ventilating the apparatus are given. The temperature of a 5000-kw. substation was lowered 11 deg. cent. by directing the exhaust air from the units.

The difficulty in providing air cooling equipment for larger units for sub-basement substations has been more or less responsible for the adoption of the oil and water cooling system, particularly for the stationary apparatus, such as transformers and the regulators. The diagram and description of the oil and water piping system show how 3850-kv-a. transformers, each containing 3100 gal. (11,730 l.) of oil, are cooled.

The nature of the foundation structure of large buildings limits the adaptation of the floor construction for the electrical apparatus, which is the reason for the comparatively high structural cost.

The floor space required for small units of 500 kw. capacity is 0.95 sq. ft. (0.088 sq. m.) per kw., and for large units of 3500 kw. capacity is 0.54 sq. ft. (0.05 sq. m.) per kw.

The plan and elevation of one of the largest and most modern substations of the sub-basement type are shown. The ultimate capacity of this substation is 16,000 kw. with a 1875-kw. battery. The floor space is 10,600 sq. ft. (985 sq. m.) and the head-room is 26 ft (7.9 m.).

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 26, 1913.

CONVERTING SUBSTATIONS IN BASEMENTS AND SUB-BASEMENTS

BY B. G. JAMIESON

The type of substation discussed in this paper is that which is located below street grade in commercial buildings of large cities. Sub-grade at once suggests valuable real estate, crowded quarters flooded basements, ventilating difficulties and machinery handling problems. Coupled with these disadvantages and risks are certain economies and other features which have made these substations a matter of much importance in our largest cities. The purpose of this paper is to show the influence of these factors upon the apparatus and arrangement of this type of substation.

In the down-town district of Chicago, for example, the development of converting substations below street level has covered a period of approximately fifteen years and in that time the capacity of single converting units has increased from 250 kw. to 3500 kw., and fortunately the building art has so advanced that head-room of from 15 to 26 ft. (4.5 to 7.9 m.) has been made available in some of the sites more recently secured. In the heart of Chicago, practically within the " loop," there are ten substations either in service or about to be commissioned which have a combined capacity of 42,000 kw. in converting apparatus or storage batteries, all operating on the Edison three-wire system, eight of which, with a total capacity of 29,000 kw., are of this sub-grade type. One of the latest substations has an ultimate capacity of four 3500-kw. and one 2000-kw. synchronous converters; one of the earliest has eight 500-kw. and four 1000-kw. converters. The district has an area of only 0.81 sq. mi. (2.1 sq. km.) and a connected load of 1,940,000 lamps (50-watt equivalent), a maximum last year of 31,000 kw. and an annual

load factor of 32 per cent. Fig. 1 shows the 24-hour load on the day of maximum kw. in the winter of 1912, and Table I shows the annual kw. increment, an interesting table, in which may be discerned indiscriminate periods of great business expansion and depression and, faintly, the advent of the tungsten lamp.

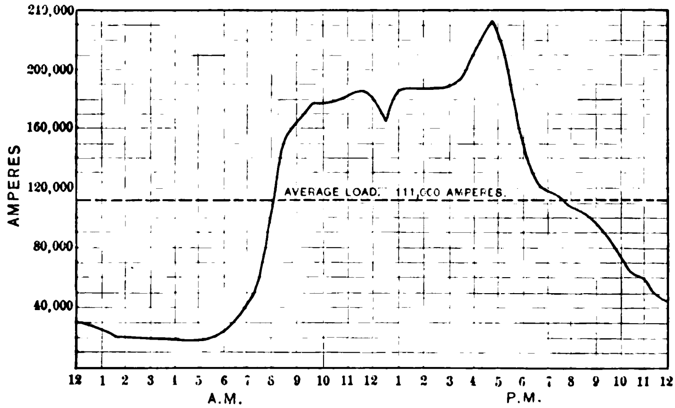


FIG. 1—LOW-TENSION DOWN-TOWN DIRECT-CURRENT LOAD ON DAY OF MAXIMUM OUTPUT—DEC. 16, 1912

Devoid of all exterior attractiveness, these converting substations may be viewed from the engineer's standpoint as a series of large, deep pits surrounded by concrete walls, upon which devolves the duty of resisting the inward thrust of the

TABLE I

PER CENT OF INCREASE OF DOWN-TOWN LOW-TENSION MAXIMUM LOAD

	Per cent
1901 over 1900	15.5 increase.
1902 " 1901	25.7 "
1903 " 1902	18.5 "
1904 " 1903	5.5 "
1905 " 1904	27.4 "
1906 " 1905	5.4 "
1907 " 1906	7.8 "
1908 " 1907	3.0 "
1909 " 1908	10.0 "
1910 " 1909	1.7 decrease
1911 " 1910	6.4 increase
1912 " 1911	4.8 "
1913 " 1912	7.0 increase (estimated)

abutting earth and of keeping out the surface and sub-soil water, bottomed with a layer of concrete which must be heavy enough to keep the earth from crowding up into the pit, and intersected vertically by numerous columns which keep

thousands of tons of steel, concrete, and tile from falling into it. Occasionally a group of fire engines may pour or a broken street main may liberate perhaps 10,000 gal. (37,854 l.) of water per minute directly over the roof of the pit which has two open stair wells, a shaft of approximately 175 sq. ft. (16.2 sq. m.) to admit apparatus, and air ducts of 50 sq. ft. (4.6 sq. m.) section; and with all this the converters must operate continuously. Quite different from the super-grade structure, the comparatively simple duty of which is to protect the apparatus from the weather.

The sub-grade substations may be grouped in two classes, I—the basement type, and II—the sub-basement type, the distinguishing feature being that Class I usually includes the sub-sidewalk space and may be reached directly from the street or sidewalk level; whereas Class II may be either a first or second

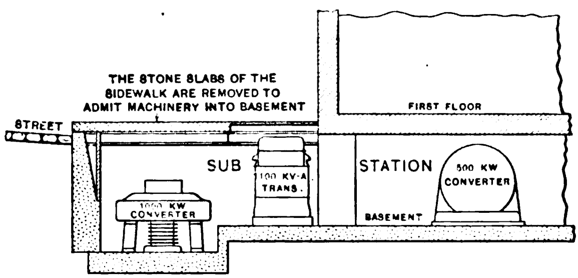


FIG. 2—SECTIONAL ELEVATION, BASEMENT TYPE

sub-basement of a twenty-story building, which is isolated from both street and sidewalk. Figs. 2 and 3 show the conventional forms of entrances to these two types.

Class I typifies the earlier stage of the development when basement space was not so valuable as now and in many ways presented proportionately as great construction problems as Class II, for, even though the depth was not so great, the adaptation of a given space for an electrical substation had to be carried out at the foundations of a high building designed without thought of such purpose.

In contrast to the ordinary super-grade substation there is no convenient 12- or 14-ft. (3.6- or 4.3-m.) doorway, with a crane just inside for admitting and handling a 7000-lb. (3175-kg.) transformer. The roof of the substation is on the level of the sidewalk and the space above the roof is another's premises. Access must be had through the sidewalk or adjacent alley.

The Class I machinery entrances are usually simply sidewalk slabs, the removal of which gives a clear opening into the substation, while Class II intakes may be expensive shafts with offsets, totaling 40 ft. (12.2 m.) in depth. Fig. 6 shows the method of lowering a 3850-kv-a. transformer through a Class II entrance. Work of this sort is exceedingly precarious and requires the utmost caution on the part of the engineer in charge; for the shifting of centers of gravity with respect to points of support, and of the points of maximum bearing pressure, are made rapidly and in a manner often not contemplated in the

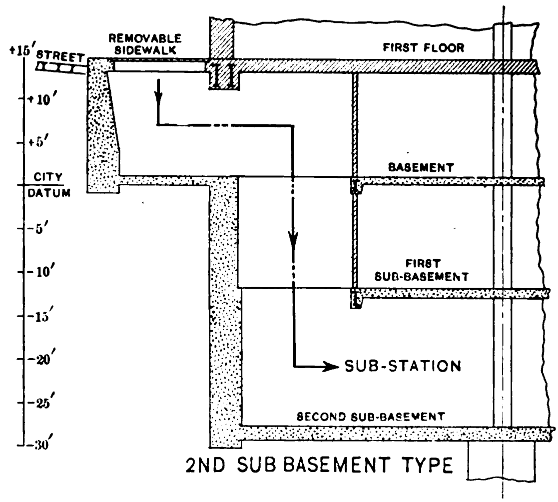


FIG. 3 —SECTIONAL ELEVATION, SECOND SUB-BASEMENT TYPE

design of apparatus. Clearances of an inch (25.4 mm.) or less are common in this class of work.

In the utilization of this entrance many untoward factors materialize. In a crowded business street only a limited time is allowed at the week-end, seldom exceeding thirty consecutive hours, in which sidewalk slabs must be removed, the machinery put in the substation space and the sidewalk slabs put back into original position. This usually means night and Sunday work to be carried out regardless of weather conditions. The effect of this close work may be reflected as far back as the factory from which shipment of apparatus is made. To illustrate—a 3500-kw. synchronous converter with its appurtenances, a gross weight of 135 tons, must be brought into the substation on a certain

[JAMIESON]

FIG. 4.—LOWERING TRANSFORMER INTO COURT PL. SUBSTATION

[JAMIESON]

FIG. 5.—MACHINERY INTAKE, SHERMAN STREET SUBSTATION

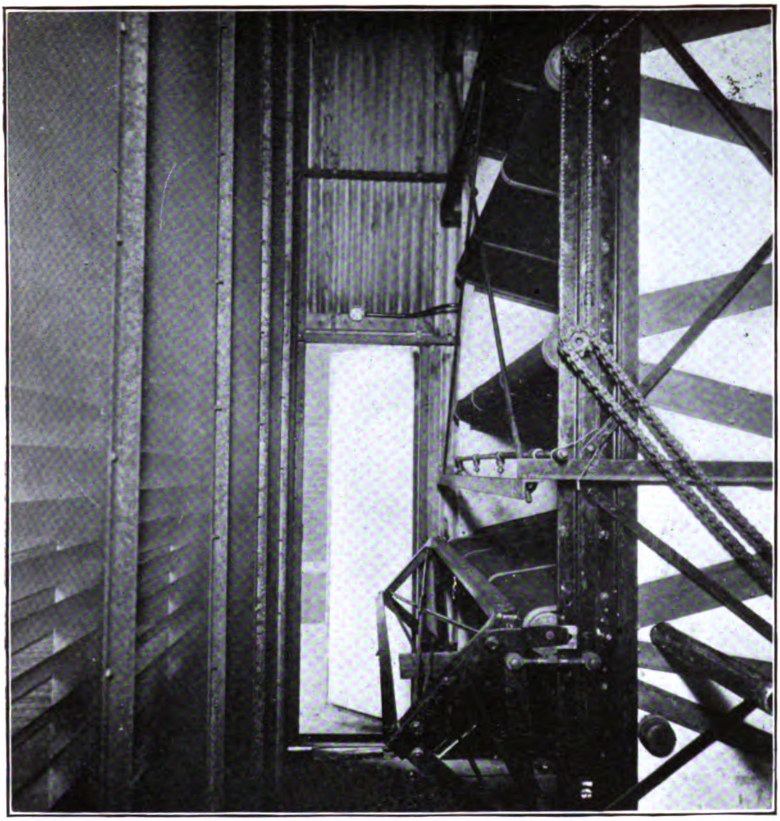


FIG. 7.—VACUUM-CLEANED AIR SCREEN, HARRISON STREET SUBSTATION [JAMIESON]

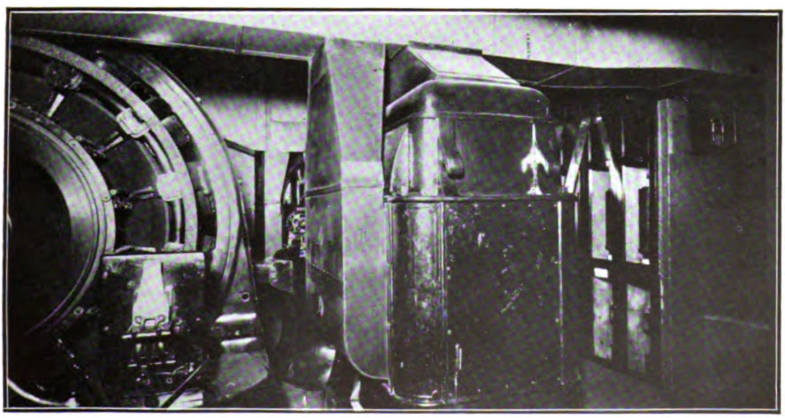


FIG. 8 [JAMIESON]

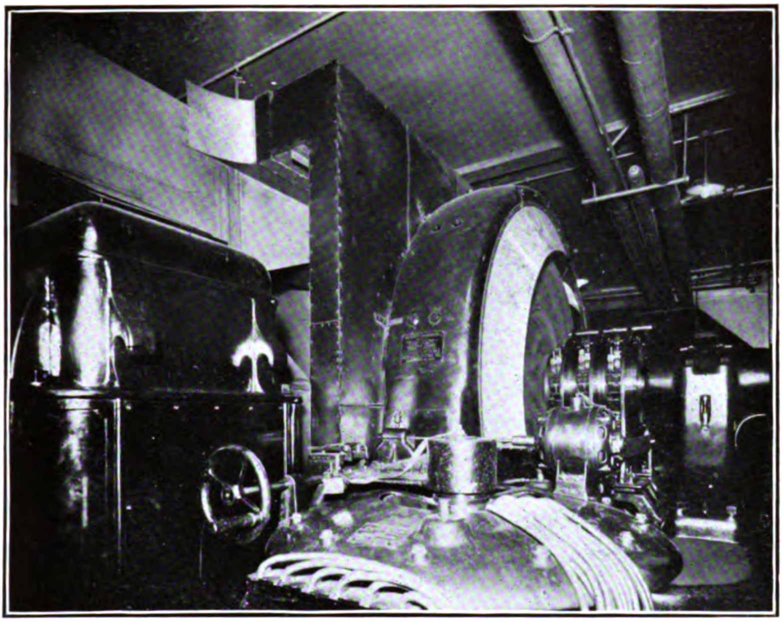


FIG. 9 [JAMIESON]

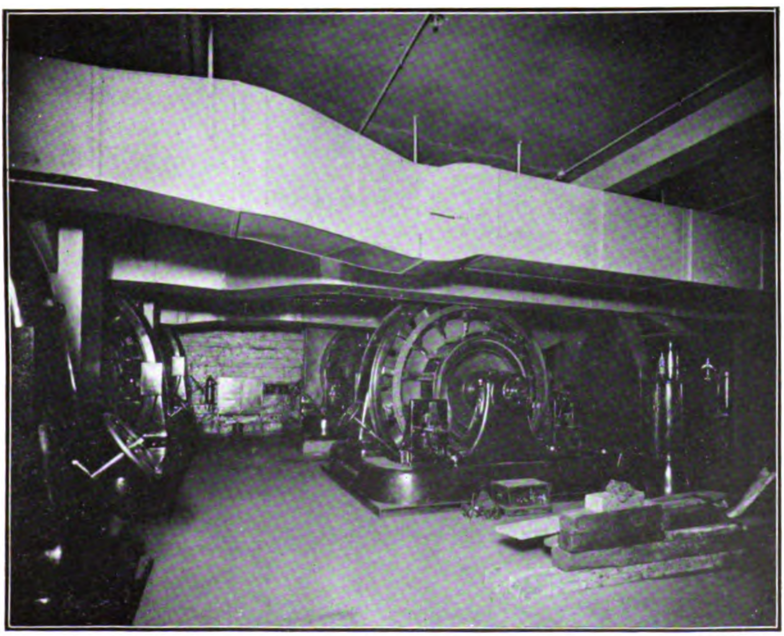


FIG. 10 [JAMIESON]

date. Factory shipment is scheduled accordingly, allowing for the vicissitudes of railway transportation, so that demurrage may be avoided. The apparatus must be especially cribbed to fit the entrance to substation, or perhaps only partially assembled or so arranged on the cars that proper order of removal may be followed; perhaps a particular 15-ton piece has to be placed on the wagon in a certain manner because it is not possible to reverse its position after loading.

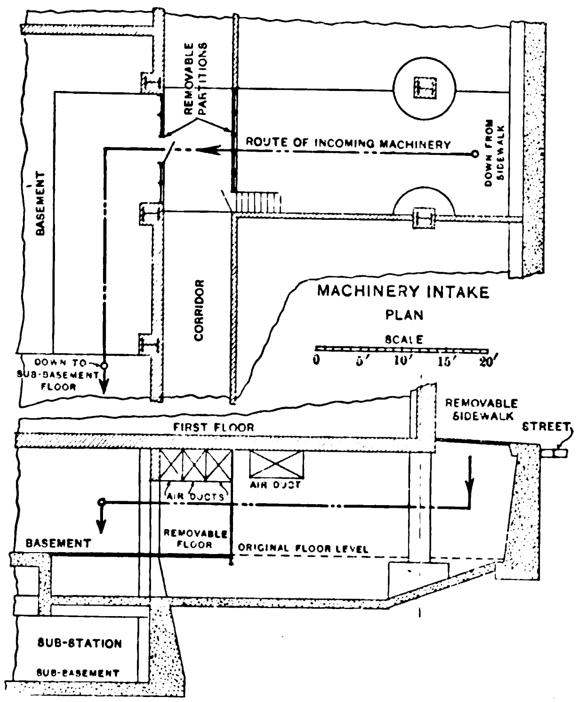


FIG. 6—PLAN AND SECTIONAL ELEVATION OF MACHINERY INTAKE

In the Class I substations, there is naturally more latitude in the choice of location for this entrance than in Class II, and consequently the work is generally less difficult. The parts to be handled are usually smaller in Class I substations, so that Class II machinery handling problems are much more serious. For instance, one substation has a machinery intake in the exact form shown in Fig. 3, the course of incoming machinery being indicated by dotted line. The apparatus may be 10-ft. (3.05-m.) cubic elements weighing 25 tons, and cribbed for two or three

inches (50 to 75 mm.) clearance. The shaft walls are lightly supported, so all weight must be taken from lowest floor. Fig. 5 shows the section of a machinery entrance and passageway in another substation under construction, which had to be practically hewn out of a finished building basement. Fig. 6 shows a diagram of this same entrance.

Of really greater importance to these substations is the matter of air supply, because until recently all synchronous converters installed on the Chicago system had air-blast transformers and regulators and required under extreme conditions 10,000 cu. ft. (283 cu. m.) of air per minute per unit of 1000 kw. capacity. The temperature characteristic of these units is a 55 deg. cent. rise with an overload of 25 per cent and in many cases 50 per cent for two hours. With the temperature of the substation at 40 deg. cent. (104 deg. fahr.) and the street level temperature at 35 deg. cent. (95 deg. fahr.), it may be seen that the problem of bringing enough air to keep, say, six such units below maximum safe insulation temperature is no small one. Besides, the air must be taken away from the substation as fast as it is introduced, in order to avoid prohibitive back pressure.

Again, a comparison with a super-grade substation may be made to emphasize the dimensions of this problem. In the latter type, one usually finds a half basement construction with numerous windows, which serve the purpose of intakes, and an array of large windows, also perhaps a monitor in the superstructure, readily permitting the escape of the heated air, or perhaps 300 sq. ft. (28 sq. m.) of doorway which can be opened at will. Referring back to the picture of the concrete enclosed pit, built close to the lot lines, and bearing in mind the usual inviolability of building lines, one may imagine the difficulties in the way of adequate air supply.

The usual method of bringing in air is through a specially designed grating in the sidewalk, which must be so located that it will not inconvenience the public or the tenant whose business is carried on just above the substation. The street level location of the air intake gives rise to one of the most serious faults characteristic of air supply systems of this sort, viz., the unavoidable entrainment of large quantities of dirt. Grating, screens, and washing devices are of but little avail against the volumes of dirt swept along with the 40,000 or 50,000 cu. ft. (1130–1410 cu. m.) of air per minute which scours the street on its way to the intake.

Again, during freezing weather ice and snow make trouble and in some cases require special construction for their control. The dirt is, however, the most serious drawback. It can be removed from the exterior of accessible surfaces more or less easily, but when blown into the air ducts of an internally cooled transformer or regulator for a period of years, the weekly cleaning of apparatus retards but slightly the inevitable clogging of these passages. Manufacturers have been slow to recognize these conditions as unavoidable, but lately have offered some aid by the provision of internal ducts of less tortuousness, which may be more effectively cleaned.

The principal objections to air cleaning chambers and devices have been first cost, space required, resistance to passage of air and operating expense. One promising new device is a screen, differing from ordinary screens, in that it is self-cleaning. That is, a motor-driven endless cloth screen travels past a fixed vacuum sweeper, and all dirt deposited can be removed as fast as desired by simply varying the rate of travel of the screen. This screen under test caused a surprisingly low drop of pressure, considering the thickness of cloth. Fig. 7 shows a partial view of this machine, viewed from the substation side.

Cooling air is drawn through the screening device, usually by blowers in duplicate and of the curved vane type, each usually having a capacity of 25,000 cu. ft. (708 cu. m.) per minute at $1\frac{1}{4}$ oz. (35.5 g.) pressure, and impelled through sub-floor ducts to the converting unit.

As constructed, air-blast synchronous converter outfits are not entirely adapted for service in these sub-grade substations. In the super-grade substations where multitudinous windows and large doors are possible, little attention is necessary to the disposal of the heated air, as the numerous exits tend to diffuse the air currents. In the sub-grade type, however, the direction that all air currents take upon leaving the room is generally towards a given point and this fact makes the cooling of adjacent converters very difficult. A synchronous converter is usually constructed as though it were intended to operate where cool air can impinge from all directions. When operating in an enclosed substation in close proximity to adjacent units where blasts of heated air are being thrown out by the complex fan action of their revolving armatures and drawn toward one corner of the room by the exhaust fan, they are subject to dangerous overheating. The transformers and regulators do not suffer

as much, proportionately, because of the structurally directed internal air blast. The obvious remedy is to treat the exhaust air as we treat the supply air, and lead it away through ducts, which is fairly easy in the case of the transformer. But to do this effectively with the synchronous converter is much more difficult. Radial, shaftwise, and eddy currents are so indiscriminate that the problem of corralling them and leading them off in ducts is very difficult without sacrificing accessibility of the working parts of the converter.

Figs. 8, 9 and 10 show some installations of this sort of exhaust duct system, which actually lowered the temperature of a 5000-kw. substation 11 deg. cent. (20 deg. fahr.).

The exhaust fan is usually a single unit of the positive blower type, in some cases of a capacity of 25,000 cu. ft. (708 cu. m.) per minute at 1½ oz. (42.5 g.). Disk fans are inadequate, because of the resistance of available exhaust passages.

After the air has performed its cooling functions it must be disposed of at its intake rate of perhaps 60,000 cu. ft. (1700 cu. m.) per minute. It cannot be returned through the sidewalk, for such a blast would be a public nuisance, so advantage is taken of every available uptake towards the roof—the building stack or its shaft, any available ventilating or conduit shaft, or perhaps a separate duct, erected against the exterior wall in the light court.

For the service from battery rooms the exhaust blower and shaft must be impervious to acid fumes, which means special construction in each case. Bronze fans or lead-lined stacks were the standards of earlier practise, but owing to cost and difficulty with lead linings in stacks of considerable height, experience is being sought with plastered ducts. In one case a steel impeller with acid-proof paint seems to have met the requirements amply.

The difficulties experienced with the air-blast type synchronous converter outfits finally forced attention towards water-cooled units, the expense of water supply having long delayed consideration of this type. Three substations are in course of erection in Chicago which will utilize converter outfits cooled by water from the city mains. These units are of 2000 and 3500 kw. capacity. Air will still be required for revolving apparatus, but with the increase in capacity and the consequent reduction in number of units per substation, the problem of adequate housing and duct work to facilitate cooling is simplified.

The city water has an average yearly temperature of 10 deg.

cent. (51 deg. fahr.) and a summer temperature of 22 deg. cent. (72 deg. fahr.), which is much lower than available cooling air previously referred to. As the 3850-kv-a. transformer requires 24 gal. (90.8 l.) of water per minute at full load with a load factor of 32 per cent the theoretical substation requirements average 2900 gal. (10,980 l.) per 1000 kw. per 24 hours. The calculation assumes the operation of units in a group of substations in exact conformity with the load curve in the district. The actual consumption will, of course, be in excess of this amount because of the manifest impossibility of accomplishing this without underloads. But since the periods of full load occur during the winter and we are dealing with absolute temperatures, overloads may be taken with less than proportionate increase in the gallons per minute consumption.

The theoretical temperature rise of this discharge water from a 3850-kv-a. transformer at full load is approximately 10 deg. cent. (18 deg. fahr.), which checks fairly well with results gained from operation of similar apparatus. This warm water, it is intended, will be wholly or partly sold to the building management, whose requirements may reach 50,000 gal. (189,270 l.) per day.

As the substations are developed and the amount of waste water attains economical significance some reclaiming or recirculating system will undoubtedly be adopted, but operating experience will afford the best guide to a selection of the proper system.

Fig. 11 shows the connections of the water and oil piping system. Attention is called to the fact that this is an open system, the street main pressure being depended upon to force water through the cooling coils and the discharge being open to atmosphere. All apparatus is, however, below the level of the street mains and sewer. Ejector pumps in duplicate are used to lift the water to the sewer from the discharge tank or to the building mains. Duplicate supply services from mains to different streets, duplicate ejector pumps and the general reliability of the water supply of a large city, all make for the security which must be a feature in a system of this kind.

In each of the 3850-kv-a. transformers there are 3100 gal. (11,730 l.) of oil which must be capable of being easily introduced, renovated, and replaced. The transformers are enclosed by compartments of concrete with doors of iron, which are practically tight. An open drain of 324 sq. in. (2090 sq. cm.) runs

beneath the several compartments and is intended to convey to a 3500-gal. (13,250-l.) pump any oil which might be suddenly liberated from the transformer casing. A considerable piping system is needed for accomplishing this. Preliminary to the design of the oil piping system opinions were asked of engineers and manufacturers, regarding the necessity of providing for quick discharge of the oil in emergencies. Operating engineers favored this provision, but the manufacturers claimed that it is sufficient to close the transformer tightly in case of fire in order to retain the oil, and smother any flames which might occur.

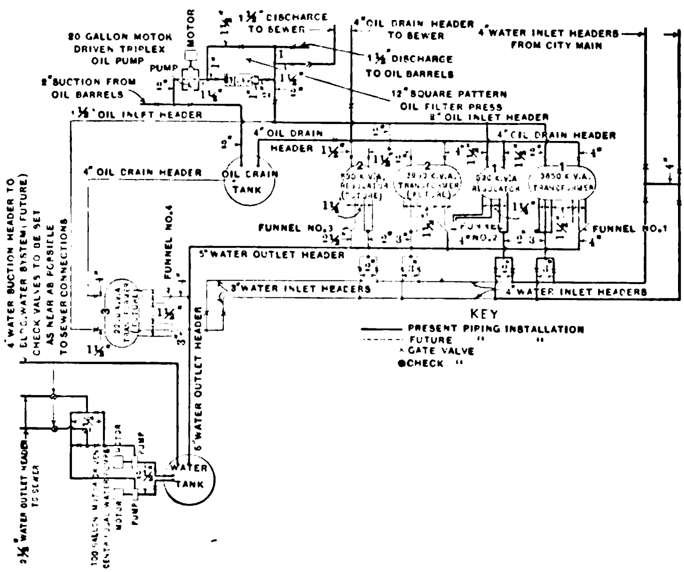


Fig. 11—Diagram of Connections for Oil and Water Piping for Transformers and Regulators

It is, of course, desirable to retain the oil in case of fire as this would undoubtedly lessen the damage to the transformer, but the oil may be liberated by an arc burning a hole through the case, in which event it may be very valuable to have means for quickly drawing off the oil.

In the diagram, Fig. 11, are several special features designed to increase the universality of the oil pipe system as much as possible, and the construction is such as to amplify in every possible way all precautionary features. The pumps, which are shown as a part of the oil filter system, are so connected that they

may serve either as filter or ejector pumps. Also the large sump shown, which is beneath the floor, may act either as a temporary storage of renovated oil or as a receiver for oil lost from a unit in service.

The reason for the apparently high structural cost of these sub-grade substations is the dual relation of the construction to the building itself and to the apparatus installed. It is expensive to construct deep walls actually proof against water leaking and to provide for locating machinery upon a floor, which serves also the purpose of holding the building together, because essential features of such a type of floor construction will generally limit its adaptation to other purposes. For instance, just at the point where cable space is needed behind a switchboard a false wall may require an extra foot (30 cm.), or just at the point where air ducts may be desired in the floor, a 36-in. (91-cm.) steel girder or its concrete equivalent may be located; or, as in one recent site, the whole floor must be reinforced so as to keep the earth below the building from being thrust upwards.

In one of the older substations where spread footing of columns claimed nearly 50 per cent of the available loading area of the basement floor, about one-half the weight of the battery, or 400 tons, had as a consequence to be carried on cantilever beams under the floor.

If the building in which the substation is to be located is an old one and only small units are to be installed, then the cost of the building construction required may be fairly low per unit but the cost per kilowatt high. If the building is an old one and the apparatus to be installed is of a size of the more modern units, then the cost of building construction per unit may be doubled, but the cost per kilowatt will be lower. If the building be a new structure and plans for substations can be made a part of building plans proper, the substation structural cost will be reduced very materially.

Building ordinances and other municipal regulations and interests play a considerable part in the development of these sites, and, together with the extraordinary nature of the business of the substation as compared with that of the average tenant of large down-town buildings, bring about some anomalous conditions. Ventilation, sidewalk restrictions, emergency exits, street and alley compensation and other matters not so prominent in ordinary construction feature strongly.

It seems quite pertinent to emphasize a fact that has a bearing

on appraisals of this portion of an operating company's invested capital in rented properties. There is probably no portion of the company's real property where large sums of money may be invested for structural purposes with so little visible result as in the construction of a system of these substations. Conduit systems are more invisible, but a simple street chart and a few unit costs afford a very accurate guide to estimating of values.

The type of apparatus installed in these substations fixes the interior construction to a great extent. Synchronous converters are here practically the only type of units in use. Gross floor spaces of 0.95 sq. ft. (0.088 sq. m.) per kw. were average figures

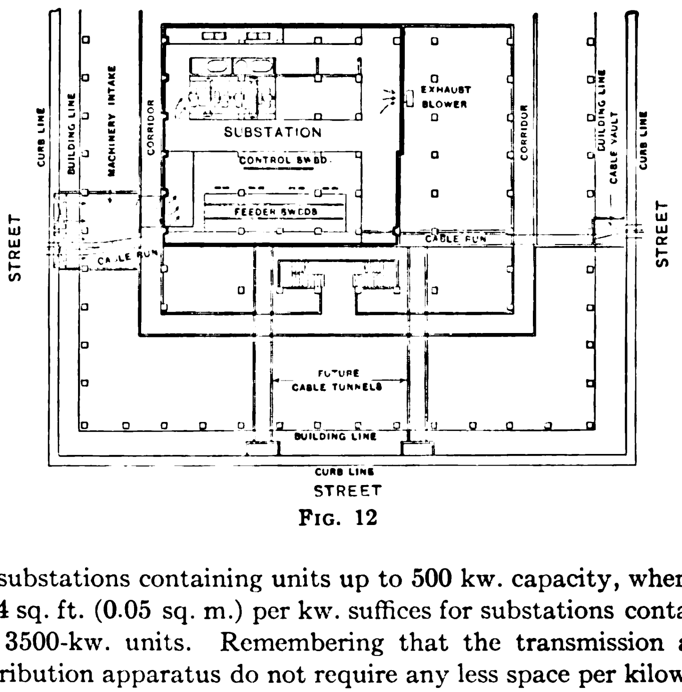


FIG. 12

for substations containing units up to 500 kw. capacity, whereas 0.54 sq. ft. (0.05 sq. m.) per kw. suffices for substations containing 3500-kw. units. Remembering that the transmission and distribution apparatus do not require any less space per kilowatt than they did with smaller units it is clear that the large units have contributed wonderfully towards economy of space.

Figs. 12 and 13 show a plan and elevation of one of the largest and most modern substations of the sub-grade type which is under construction. This substation has 26 ft. (7.9 m.) head room, and floor space, including gallery, of 10,600 sq. ft. (985 sq. m.), which will permit of 16,000 kw. in converter capacity and a battery capacity of 1875 kw. (one-hour rate). One con-

spicuous feature is the ease of access to the conduit system in the three adjoining streets, a feature so seldom secured. The machinery intake is on a wide street where the volume of traffic is comparatively small, which is favorable both for machinery handling and air supply. Boilers in an adjoining room will assist in the disposal of heated air from the substation by their combustion requirements and may also help to dispose of the cooling water.

Favorable conditions such as these are not to be had with all

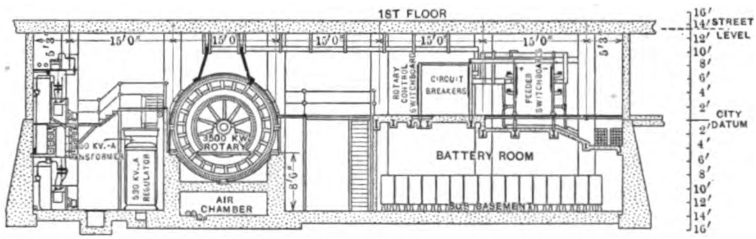


FIG 13 —SECTIONAL ELEVATION OF SUBSTATION SHOWN IN FIG. 12

sites secured, since many factors other than electrical or physical determine availability of locations, but withal the number and size of these prospective substations are rapidly increasing.

Because of the desire to treat these substations as a type, individual descriptions have been omitted and the characteristics of the type emphasized; for, with the increasing values of real estate in other large cities it is probable that this type of substation will awaken in the future a greater interest among electrical engineers.

COMMUTATING-POLE SATURATION IN D-C. MACHINES

BY

HAROLD E. STOKES

Presented under the auspices of the

Industrial Power Committee

COMMUTATING-POLE SATURATION IN D-C. MACHINES

BY HAROLD E. STOKES

ABSTRACT OF PAPER*

The paper discusses the importance of obtaining the characteristic curve of the commutating-pole useful flux, especially in regard to machines designed to withstand heavy overloads. It is pointed out that this curve must not depart from the curve representing the flux required to neutralize the reactance volts of the machine by more than an amount corresponding to a reactance voltage which experience has shown can be successfully taken care of by the resistance of the brush

A method of measuring the useful and total commutating-pole flux is described. The results of tests on two machines are given, together with curves showing the useful and total fluxes obtained.

The importance of the ratio of leakage flux to useful flux at low saturations, in regard to maintaining and determining the ultimate point of reversal of the useful flux, is shown. An approximate formula for obtaining the useful flux from this ratio is given.

An attempt has been made to analyze the magnetic leakages due to the main and commutating-pole ampere-turns and to show that the paths taken by and the dimensions of these fluxes are to a certain extent dependent on the relative values of the main and commutating-pole ampere-turns.

The variation in the relative values of the main and commutating-pole ampere-turns and the absence of uniformity in the magnetic potential of the commutating pole introduces some degree of error into the formula given. To obtain a greater degree of accuracy, corrections have to be made for the varying initial leakage ratio and for the change of magnetic density existing at different points in the length of the commutating pole.

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 25, 1913.

COMMUTATING-POLE SATURATION IN D-C. MACHINES

BY HAROLD E. STOKES

The saturation of the commutating pole is one of the principal factors upon which depends the satisfactory operation of d-c. commutating-pole machines. This is especially the case in such classes of machines as d-c. rolling mill motors, railway generators and other d-c. machines having to withstand heavy momentary overloads. Owing to the difficulty of measuring the fluxes combining to produce saturation, under normal working conditions, by other than sensitive laboratory tests, the designing engineer's knowledge of the phenomena attending the commutating-pole fluxes has lagged somewhat behind their application in commercial practise.

Test have been made at various times, by different engineers, to ascertain the saturation of commutating poles, and as far as the author knows, a method of test employing the ballistic galvanometer has always been used. This is necessarily a test involving considerable refinement and can scarcely be considered a commercial test floor method. Hence, most designers have been satisfied with obtaining sparkless commutation, or if brush potentials gave them an approximate indication of the working saturation of the commutating pole.

A method of obtaining iron saturations and losses has been used by Dr. Gisbert Kapp for transformers and other stationary apparatus, which consists in varying the flux density by changing the excitation, and observing the time of change, the exciting ampere turns and the voltage induced in an auxiliary coil enclosing the iron section carrying the fluxes to be investigated. This method has been adapted by the author for the

purpose of obtaining commutating pole saturations under normal working conditions. Satisfactory results have been obtained and owing to the method being devoid of the extreme refinement necessary to secure good results by the ballistic method, can frequently be employed by the ordinary test floor staff.

The machine to be tested has the armature fixed to prevent movement and the various windings—armature, series, shunt coils and commutating pole coils—connected for operation as a motor. The shunt coils are excited to their normal value of current. A coil consisting of a few turns of flexible wire is wound around the commutating pole at the point to be investigated, and the ends connected to a millivoltmeter.

By varying the current flowing through the commutating pole coils, a deflection is obtained on the millivoltmeter due to the varying flux at the part of the commutating pole embraced by the coil. By suitably varying the current through the machine so as to obtain an almost constant deflection on the millivoltmeter, observations of main current, millivoltmeter deflection and time in seconds, can be made. From these observations, the saturation of the commutating-pole at various loads and under working conditions can be calculated.

The determination of the best number of turns and resistance to be used in the exploring coil and the method of calculation are as follows:

$$e = T \frac{dN}{dt} 10^{-8} = TA \frac{dB}{dt} \cdot 10^{-8}$$

and

$$10^8 \frac{e}{TA} = \frac{dB}{dt}$$

Integrating, we have

$$\int_0 10^8 \frac{e}{TA}\, dt = \int_0^B dB$$

$$\frac{e}{TA}\, t\, 10^8 = B, \text{ and } t = \frac{BTA}{e\, 10^8}$$

$$e = \frac{BTA}{t\, 10^8}$$

Where e = Volts induced in exploring coil
T = Number of turns in exploring coil.
A = Cross-section area of commutating pole.
N = Flux linking exploring coil.
T = Time in seconds.
B = Flux density in commutating pole.

The approximate commutating-pole flux entering the armature is known to the designer and is of a dimension, say 500,000 c. g.s. lines. The commutating-pole section is say 100 sq. cm., giving $B = 5000$. A time of about 25 seconds is necessary to vary the main current from zero to the maximum value and obtain the necessary readings. A reading of two millivolts is assumed and the number of turns in exploring coil follows from the above formulas:

$$0.002 = T \times 100 \frac{5000}{25} \times 10^{-8}$$

$$T = \frac{0.002 \times 25 \times 10^{8}}{100 \times 5000} = 10$$

The resistance of the coil should be low enough so as not to absorb a large proportion of the induced volts in the exploring coil. The actual volts induced
e = millivoltmeter reading multiplied by

$$\frac{\text{resistance of millivoltmeter} + \text{resistance of exploring coil}}{\text{resistance of millivoltmeter.}} \quad (1)$$

Generally speaking, if the resistance of the exploring coil does not exceed about 0.2 to 0.3 ohms, while the resistance of a millivoltmeter reading 10 millivolts full scale reading, is 1.0 ohm, satisfactory results will be obtained even on small machines with a commutating-pole flux of small dimensions.

Formula (1) is based on a constant $\frac{\text{change of flux}}{\text{change of time}}$ giving a constant induced voltage in coil, but as in practise it is difficult to vary the current in the machine at such a rate as to give a constant change of flux with regard to time, it is sufficient if the current is varied at such a rate as to enable the operator to obtain steady voltage readings, taking periodically every three seconds simultaneous readings of current and time.

Connections are made as in Fig. 1; the shunt coils are separately excited to normal value and a booster capable of giving three or four times full load current is used to supply current to the machine undergoing the test. The current is varied at a suitable rate by means of a rheostat in the booster field, which is separately excited. With the exploring coil around the tip of commutating-pole, starting from zero, increase the current through the machine at a suitable rate; take readings as described above until, as the commutating-pole approaches saturation, the millivoltmeter reading begins to decrease.

At the point where the commutating-pole flux entering the armature reaches a maximum value, the millivoltmeter will be reading zero and any increase in the load current will result in a decrease in the flux entering the armature and threading the exploring coil. This decrease will produce a reverse reading in the millivoltmeter.

A complete set of positive and reverse readings should be taken until the load current is carried as high as conditions will permit. The change of flux can be calculated for each set of readings taken, from formula (**1**), by substituting time in seconds between each reading and volts obtained on the millivoltmeter. From the summation of the fluxes thus obtained, a saturation curve can be plotted, showing flux and exciting ampere turns.

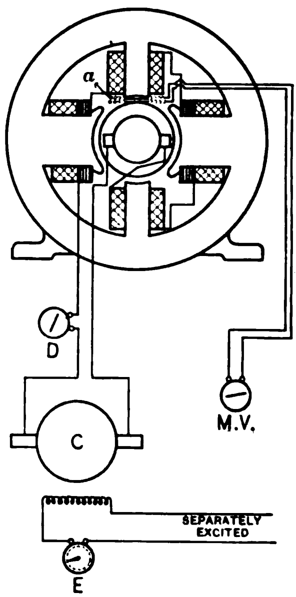


FIG. 1

A. Exploring coil.
M.V. Millivoltmeter, double reading.
C. Booster capable of supplying current to required limit and with field separately excited.
D. Ammeter in series with armature, series and commutating coils.
E. Booster shunt field rheostat.

Fig. 2 shows a saturation curve (a) taken at the commutating-pole tip while curve (b) shows commutating-pole saturation at the junction with the frame. To obtain curve (a), the load current was increased until the direction of the interpole flux entering the armature was reversed at point X, due to the commutating-pole ampere turns being all absorbed in balancing the armature ampere turns and in pushing the leakage flux through the commutating-pole. To obtain curve (b), the exploring coil

was placed round the commutating-pole as near to the magnet yoke as possible. Readings were taken as for curve (*a*). The leakage ratio, at any load, is given by $b - a/a$ and is practically constant until the flux approaches the knee of the saturation curve.

While it is of only secondary importance to know the point in the load at which the useful flux becomes zero, it is of great importance to be able to predetermine the useful flux at the maximum overload at which the machine is to operate. Satisfactory commutation at the maximum overloads is dependent on a reasonably accurate predetermination of the useful commutating-pole flux.

Fig. 3 shows the ampere turns on the commutating-pole available for driving the useful flux into the armature. $O\ B$

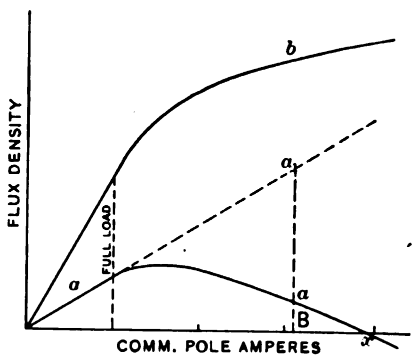


FIG. 2
Curve (*a*) shows useful commutating pole flux entering armature.
Curve (*b*) shows commutating pole flux against yoke.

shows interpole ampere turns plotted against load current. With a ratio

$$\frac{\text{commutating-pole ampere turns}}{\text{armature ampere turns}} = 1.5,$$

$O\ A$ represents armature ampere turns at any load. The horizontal length between $O\ B$ and $O\ C$ shows the ampere turns taken to push the useful and leakage flux through the commutating-pole iron; thus, at full load, the iron ampere turns are almost zero, while at two and one half times full load the iron ampere turns are represented by $A''\ B''$.

The excess of commutating pole over armature ampere turns, is given at full load by $D'\ B' - D'\ A' = A'\ B'$, and as the iron ampere turns are negligible, the full amount $A'\ B'$ is available to push the useful flux into the armature. At two and one half

times full load the iron ampere turns are shown by $C'' B''$ and are equal to the excess ampere turns $A'' B''$. At this point in the load, the ampere turns required to balance the armature ampere turns are given by $D'' A''$, and the excess is all absorbed in pushing leakage flux through the commutating pole, so there is left zero ampere turns to push useful flux into the armature. At this point, therefore, the useful flux becomes zero, and corresponds to point X in Fig. 2. At loads greater than two and one half times full load, the ampere turns to push the leakage flux through the commutating pole exceed the excess ampere turns and there are insufficient ampere turns to balance the armature; in consequence the direction of the useful flux is reversed.

Fig. 3 is useful in obtaining a clear conception of the forces

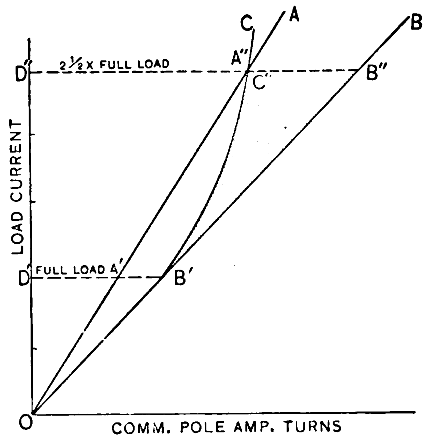


FIG. 3

acting at various loads to produce the useful flux for commutation; the length $A' B'$ may be considered as representing reactance volts at full load due to the reversal of the current in the armature coils undergoing commutation. The shaded area shows at any load, the uncompensated reactance volts and this figure should not exceed the permissible value for successful operation at the maximum overload at which the machine is to operate.

Tests made on machines of different characteristics show a wide difference in the point X (Fig. 2) at which load current the reversal of the useful commutating-pole flux takes place. An eight-pole generator designed for normal overload capacity showed the reversal point X occurring at about four times full load current, while a six-pole machine showed the useful flux to

be still about 70 per cent of its maximum value at a load of five times full load; the reversal point X would probably not occur until a load current of 10 to 12 times full load current was reached.

In Fig. 2, the dotted line $a\ a'$, drawn through the straight part of curve (a), the useful flux, represents, in its ordinates, the reactance volts at any load, thus $a'\ B - a\ B$ gives the uncompensated reactance volts, to a certain scale, corresponding to the load b. It is therefore important that the actual curve $a\ a$ should lie along the straight line $a\ a'$ within the limits of operation of the machine. The part $a'\ a$, representing the dimension of uncompensated reactance volts, should not be greater than experience shows to be the maximum for reasonably sparkless commutation.

A consideration of Fig. 2 shows that the surprising difference at which the point X occurs, in six- and eight-pole machines, is due mainly to the leakage ratio R, at the straight part of the leakage and useful curves occurring at light loads. This ratio is termed the initial leakage ratio throughout the following discussion. In the eight-pole machine, the initial leakage ratio was found to be about 2.15, while the six-pole machine gave a figure of 1.0.

The symbols given are used in the following discussion.

B_u = Useful flux density in air gap of commutating pole.

B_l = Leakage flux density in commutating pole at yoke.

B_t = Total flux density in commutating pole at yoke $= B_u + B_l$

K_u = Coefficient of useful flux = gap length $\times$ 0.8 $\times$ gap. coefficient.

K_l = Coefficient of leakage flux = effective leakage gap length $\times$ 0.8.

$A.T.$ = Ampere turns.

$A.T_e$ = Total ampere turns on commutating pole minus armature ampere turns

$A.T_a$ = Ampere turns for pushing leakage flux across effective leakage space.

$A.T_t$ = Total commutating pole ampere turns.

$A.T_i$ = Total iron ampere turns for useful and leakage flux.

$$R_l = \frac{A\ T_t}{A\ T_e}$$

$$= \frac{\text{Total commutating pole ampere turns}}{\text{Total commutating pole ampere turns} - \text{armature ampere turns}}$$

Fig. 2 shows that until some degree of saturation is reached in the commutating pole, the curves showing the useful and total flux are straight line curves, and hence the leakage flux, *i.e.*, total flux minus useful flux, is also a straight line curve for so long as the total and useful curves are straight. It is therefore evident that the leakage gap can be represented by a certain definite equivalent gap length with the total ampere turns as effective over that gap length. The above symbol K_l is thus obtained:

$$A.\,T_a = B_l \times K_l, \text{ and } K_l = \frac{A.\,T_a}{B_l}$$

For the purpose of this discussion, it is assumed that the commutating-pole is of uniform section from tip to junction with the yoke and therefore B_u in gap will also be of the same dimension as B_u in the pole.

$$A.\,T_t = K_l\,B_l + A\ T_i$$

and

$$A.\,T_e = K_u\,B_u + A\ T_i = \frac{A.\,T_t}{R_l}$$

substituting for $A\ T_t$, and

$$\frac{K_l\,B_l + A\ T_i}{R_l} = K_u\,B_u + A\ T_i$$

$$K_l\,B_l + A\ T_i = R_l\,K_u\,B_u + R_l\,A\ T_i, \text{ and } B_l = B_t - B_u$$

Therefore

$$K_l\,B_t - K_l\,B_u = R_i\,K_u\,B_u + R_l\,A\ T_i - A\ T_i$$
$$K_l\,B_u + R_i\,K_u\,B_u = K_l\,B_t - R_l\,A\ T_i + A\ T_i$$
$$B_u\ (K_l + R_i\ K_u) = K_l\,B_t - A\ T_i\,(R_l - 1)$$

$$B_u = \frac{K_l\,B_t - A\ T_i\,(R_l - 1)}{K_l + R_l\,K_u} \tag{1}$$

With known values of K_l, K_u and R_l, the formula becomes simply

$$B_u = (X)\,B_t - (Y)\,A\ T_i$$

By assuming a series of values for B_t, the corresponding values

of B_u can be directly determined. The values of load current corresponding to values of B_u can then be obtained.

$$A\,T_a = B_l \times K_l$$

where

$$B_l = B_t - B_u$$

$$A\,T_t = A\,T_i + A\,T_a$$

$$\text{and load current} = \frac{A\,T_t}{\text{commutating-pole turns.}}$$

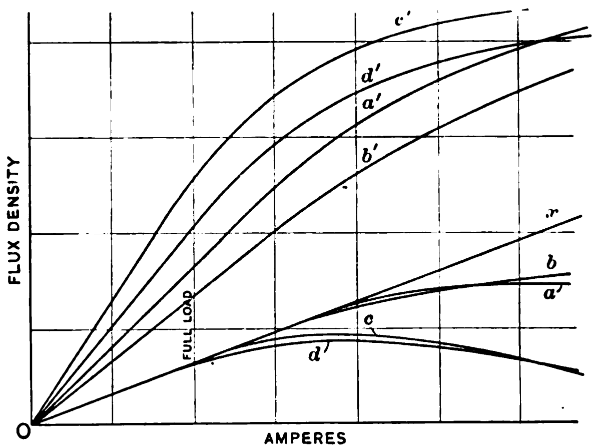


FIG. 4

Curves *a a*........ $K_l = 2.2$, $K_u = 1.53$ $\dfrac{\text{Comm. pole } A.\,T.}{\text{Armature } A.\,T.} = 1.9$

Curves *b b*........ $K_l = 2.2$, $K_u = 0.645$ $\dfrac{\text{Comm. pole } A.\,T.}{\text{Armature } A.\,T.} = 1.35$

Curves *c c*........ $K_l = 1.1$ $K_u = 1.53$ $\dfrac{\text{Comm. pole } A.\,T.}{\text{Armature } A.\,T.} = 1.9$

Curves *d d*........ $K_l = 1.1$, $K_u = 0.645$ $\dfrac{\text{Comm. pole } A.\,T.}{\text{Armature } A.\,T.} = 1.35$

From the machines tested, the values of R_l, K_u and K_l were obtained. These values were substituted in formula (1) and values of B_u and B_t obtained and plotted against the load current. The tested and calculated values of B_u agreed pretty closely. In making the calculation, the $A\,T_i$ were taken for a uniform density along the full length of pole and even with this approximation, the calculated B_u did not differ more than 13 per cent from the tested figure up to a load of about four times full load current.

Fig. 4 shows a series of calculated curves plotted for the eight-pole machine, tested with varying values of initial ratio, R, K_l and K_u. From these curves it is seen that the dimension of K_l is the principal factor in keeping the useful flux Bu along the straight line drawn through the initial useful flux line. Thus if K_l is low, the curve showing B_u will fall away from the straight line representing reactance volts, marked X in Fig. 4, at lower values of load current than for high values of K_l. These curves also show that R_l, or stated in another way, the ratio

$$\frac{\text{commutating-pole } A\ T}{\text{armature } A\ T}$$

has little effect in maintaining the curve B_u along the straight line X. Curves $a\ a'$ and $b\ b'$ show the useful and total commutating pole flux with $K_l = 2.2$ and $K_u = 1.53$ and 0.645 respectively. The useful flux curve sticks closely to the line $O\ X$ representing reactance volts up to a point corresponding to twice full load current. The curves $c\ c'$ and $d\ d'$ show the useful and total flux with $K_l = 1.1$ and $K_u = 0.645$ and 1.53 and giving ratios of $\frac{\text{commutating-pole } A.\ T.}{\text{armature } A.\ T.} = 1.35$ and 1.9 respectfully. In both these cases the useful flux curve drops off rapidly at about 1.45 times full load current. The usefulness of the higher ratios $\frac{\text{commutating-pole } A.\ T.}{\text{armature } A.\ T.}$ is offset by the increased initial ratio of $\frac{\text{leakage flux}}{\text{useful flux}}$

In using the formula

$$B_u = \frac{K_l\, B_r - A\ T_i\,(R_l - 1)}{K_l + R_l\, K_u}$$

to ascertain the commutating characteristics of a new design at the maximum operating loads, it is necessary to obtain the values of K_u and K_l; the former may be readily figured as given above $K_u = l_g \times 0.8 \times K_g$

Where l_g = commutating-pole gap length in cm.

K_g = gap coefficient as obtained by Carter's or Arnold's method.

To determine the dimension of K_l, a consideration of the paths taken by the commutating-pole and main pole leakage and their dependence on the relative magnetomotive forces producing them, is necessary. It has been shown* that the useful armature fluxes due to the main and commutating-poles in any part of the iron circuit, are given by the algebraic sums of the values of

$\frac{\text{magnetomotive forces}}{\text{reactance}}$ producing the flux in the path under consideration.

Figs. 5 and 6 show the distribution of the useful fluxes in the magnetic circuits of a two-pole machine with commutating poles. Fig. 5 shows the main poles excited while the commutating

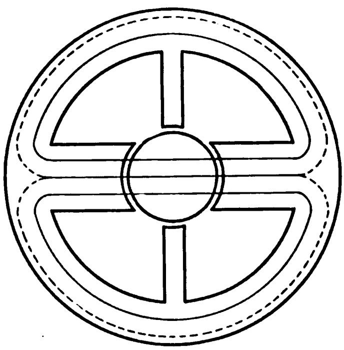


FIG. 5

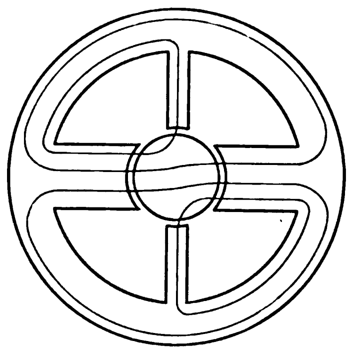


FIG. 6

poles are unexcited. Three lines are shown in the main air gap, a dotted line representing one-half line. Fig. 6 shows the same excitation of the main poles and in addition the commutating poles are excited so that there is one line in the commutating-pole air gap.

These figures show that the part of the frame forming a path common to the main and commutating-pole flux has its flux density increased by one-half of the commutating-pole flux, when the commutating-pole is excited; that part of the frame forming a path not common to the main and commutating-pole flux has the flux density reduced by one half of the commutating-pole flux.

By applying a similar process of reasoning, it can be shown that the main and commutating-pole leakage fluxes follow a closely similar distribution to that of the useful fluxes.

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* Brunt in *Electrical Review and Western Electrician*, Sept. 9, 1911, p. 514.

In Fig. 7, the leakage paths of main and commutating poles are shown, the magnetomotive forces being represented by E and e for main and commutating poles respectively. The flux and reluctances of the various paths are represented by I, R and r. Applying Ohm's and Kirchoff's laws, the fluxes in the various paths, with an assumption of a constant reluctance will be as given below.

With only main poles excited

$$I_1 = \frac{2\,E}{2\,R_1 + R_2 + R_3}$$

$$I_2 = I_3 = I_4 = I_5 = \frac{E}{2\,R_1 + R_2 + R_3}$$

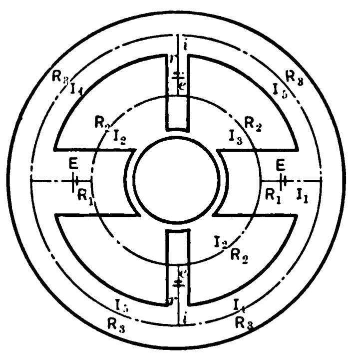

FIG. 7

With only commutating poles excited

$$i = \frac{2\,e}{2\,r + R_2 + R_3}$$

and

$$I_2 = I_3 = I_4 = I_5 = \frac{e}{2\,r + R_2 + R_3}$$

With both main and commutating poles excited.

Since the effect of the two main poles on the commutating poles is to neutralize one another as is also the effect of the two commutating poles in regard to the main poles, then the flux in the commutating poles and main poles will be the same for the same excitation, as for the cases considered with main and com-

mutating poles individually excited without the other. The flux in the leakage paths between poles is given by the following:

$$I_2 = I_4 = \frac{E}{2\,R_1 + R_2 + R_3} + \frac{e}{2\,r + R_2 + R_3} \tag{3}$$

$$I_3 = I_5 = \frac{E}{2\,R_1 + R_2 + R_3} - \frac{e}{2\,r + R_2 + R_3} \tag{4}$$

A comparison of formulas **1**, **2**, **3** and **4** shows that the leakage flux after the introduction of the commutating-pole excitation, is increased in the paths common to both main and commutating-pole leakage, by one half of the commutating-pole leakage. In the paths not common to both fluxes, the flux is decreased by one-

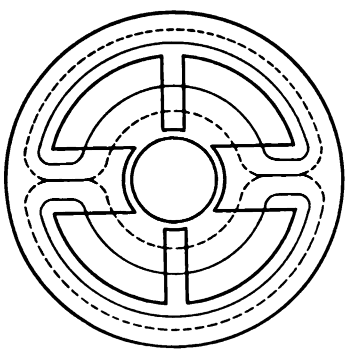

FIG. 8

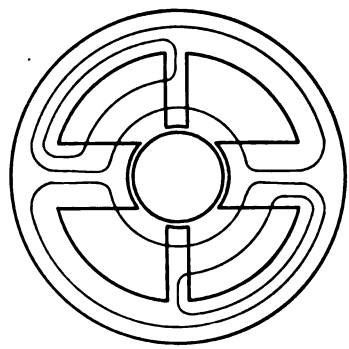

FIG. 9

half the commutating-pole leakage flux. The distribution of the commutating-pole leakage flux is therefore very similar to that of the useful flux.

Figs. 8 and 9 show the distribution of three leakage lines before and after the commutating pole is excited. Compare these with Figs. 5 and 6 showing the distribution of the useful armature flux.

At low saturation, R_1, r and R_3 may be neglected and equations **3** and **4** become

$$I_2 \text{ and } I_4 = \frac{E}{R_2} + \frac{e}{R_2} = \frac{E + e}{R_2}$$

$$I_3 \text{ and } I_5 = \frac{E}{R_2} - \frac{e}{R_2} = \frac{E - e}{R_2}$$

The main pole leakage becomes

$$I_1 = \frac{2E}{R_2}$$

The commutating pole leakage becomes

$$i = \frac{2e}{R_2}$$

At a point in the load where $E = e$, and assuming that the leakage paths of the main and commutating poles have the same reluctance, the leakage is all absorbed by the commutating pole. Fig. 10 represents the leakage flux distribution for this condition. If the machine under consideration is shunt or com-

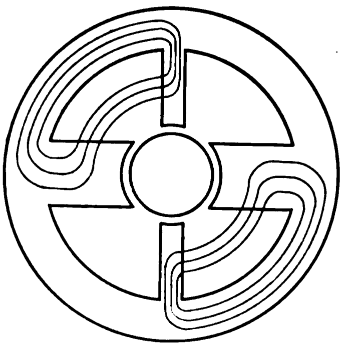

FIG. 10

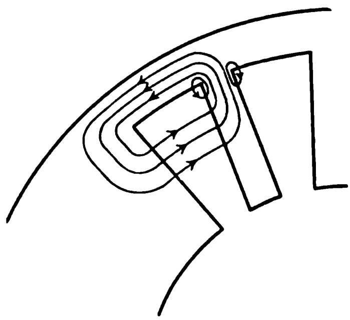

FIG. 11

pound wound, a further increase in the load current would give $e > E$. As in all normal designs, the total main flux is considerably in excess of the commutating pole fluxes, the distribution of the leakage flux will always be similar to that shown on Fig. 11, *i.e.*, the commutating pole fluxes will take a path through one of the adjacent main poles and will not travel completely round the magnet frame to the next commutating pole. Thus at loads when $e > E$, the commutating pole leakage comprising the excess of commutating pole leakage over main pole leakage must take a local path as shown in Fig. 11.

Some leakage taking a local path, however, exists before the point in the load is reached, at which $e > E$.

Fig. 12 shows a two-pole commutating pole machine, having a mean air leakage path of $2\,l$ or l per pole. The mean leakage path to the frame is l_1.

At a point A in the frame, there will be a leakage due to the left-hand commutating pole, proportional to

$\frac{A.\,T.}{l_1}$, where $A.\,T.$ = ampere turns per commutating pole.

Due to the right-hand commutating pole there will be a leakage to A, proportional to $\frac{A.\,T.}{l_2}$ but in the opposite direction to leakage due to left-hand commutating pole. Hence the actual leakage in path l will be proportional to

$$\frac{A.\,T.}{l_1} - \frac{A.\,T.}{l_2} = A.\,T.\,\frac{l_1 - l_2}{l_1\,l_2}$$

In a two-pole machine, the difference between the lengths l_1 and l_2 is much greater than the difference existing in say a twelve-pole machine. On this account the local leakage or leakage direct to the frame, will be generally much greater in machines with a low number of poles, than in machines having a high number, the same ampere turns per pole and length of local leakage path l_1, prevailing in either case. This effect is, however, more than overbalanced by the decreased length of the path l, and the consequent increase of leakage direct to the pole occurring in machines having a high number of poles.

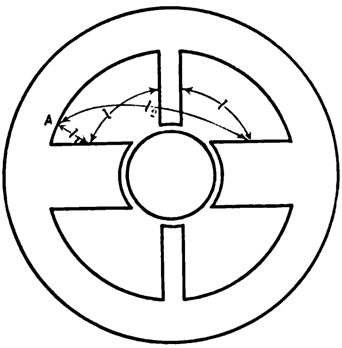

FIG. 12

The local commutating pole leakage will have, in addition to path l, paths l_3 at the ends of the commutating pole, toward the commutator and rear end. This leakage will also be modified by the adjacent commutating pole as described above in connection with the local leakage at the sides.

The local leakage paths should generally be treated separately and summed up into a single expression

$$N_l = \frac{A.\,T.}{l_l}$$

N_l = local leakage per commutating pole.

N_d = direct pole to pole leakage per commutating pole.

N = total leakage = $N_l + N_d$
N_m = direct main pole leakage per pole.
$A.T.$ = ampere turns per commutating-pole.
l_l = mean corrected length of the local paths.
l_d = mean length of direct pole to pole paths.

The direct commutating pole leakage, *i.e.*, pole to pole leakage, may be treated in a similar manner, a number of paths plotted and a resultant expression obtained:

$$N_d = \frac{A.T.}{l_d}$$

The total leakage per pole, before saturation is reached will then be given by the expression, $N = N_l + N_d$.

It does not necessarily follow, even before saturation occurs in the iron parts of the leakage path, that N will be proportional to the $A.T.$ of the commutating pole as there are other factors exercising an influence. Consider a shunt machine; at light loads $e < E$, and, assuming no saturation in the iron parts of the leakage path, the direct leakage N_d, is proportional to the ampere turns on the pole; this statement also applies to the local leakage N_l. At load where $e > E$ the direct leakage N_d will remain stationary while N_l will increase proportionally with the load and ampere turns on the commutating-pole. Further, it may happen that the main pole leakage taking the low resistance path through the commutating-pole, has the effect of producing some degree of saturation in the commutating pole. In cases of normally designed machines, it does not seem that this factor has much influence, however.

From the above it is seen that there may be two different dimensions of initial leakage, the earlier one, in point of load, being given by the expression

$$N = \frac{A\ T}{l_l} + \frac{A\ T}{l_d}$$

The second dimension occurring after a point in the load has been reached where the commutating pole leakage is greater than the main pole leakage, will be given by

$$N = \frac{A\ T}{l_l} + \frac{A\ T_b}{l_d}$$

Where $A\ T_b$ = the commutating pole ampere-turns at a load where the direct commutating pole leakage balances the direct main leakage; thus in a shunt machine, the latter part of the formula $\left(\frac{A\ T_b}{l_d}\right)$, will be a constant at all loads higher than that at which the balance between direct main and commutating pole leakage is reached.

To obtain close results when figuring the value of B_u from the formula

$$B_u = \frac{K_l B_t - A\ T_i (R_l - 1)}{K_l + R_l K_u}$$

it is therefore necessary to obtain two values of K_l, one for N/NM and the other for N/N_m. K_l will always have two values, excepting the case of a series wound machine, when N/N_m will have an almost constant relation.

It was previously stated that the commutating pole ampere turns, $A\ T_i$, were taken for the density at the root of the pole, in using the formula for B_u. This, obviously, is not quite correct, as the density tapers off towards the armature; however, from the author's experience, a comparison of calculated and test results appears to show sufficiently near results to justify the approximate method.

SUGGESTED SPECIFICATIONS FOR TESTING HIGH-VOLTAGE INSULATORS

BY

F. W. PEEK, JR., J. A. SANDFORD, JR.,
and PERCY H. THOMAS

Presented under the auspices of the

High-Tension Transmission Committee

SUGGESTED SPECIFICATIONS FOR TESTING HIGH-VOLTAGE INSULATORS

(1) BY F. W. PEEK, JR., (2) BY J. A. SANDFORD, JR., AND (3) BY PERCY H. THOMAS

Introduction

As an outcome of the New York meeting of the Institute, last December, at which meeting were presented and discussed two papers bearing on the subject of insulator testing, the High-Tension Transmission Committee is endeavoring to draw up a " model " or " skeleton " insulator test specification, which may be approved either by the High-Tension Transmission Committee or the Standards Committee or by the Board of Directors. In pursuance of this object, the Committee has secured two tentative specifications (1) that of Mr. Peek, written from the point of view of the expert tester and scientist, and (2) that of Mr. Sanford, written from the point of view of the manufacturer. The Chairman of the Committee has prepared a single specification (3) from these two, in the light of comments thereon received from the High-Tension Transmission Committee and others, and has endeavored to embody in a single specification, the best features of the other two. These three specifications follow.

It is requested that all engineers having any suggestions or criticisms to make concerning any one of these three specifications will either be present in person and offer their comments in the oral discussion or will communicate these to the Secretary of the Institute or the Chairman of the Committee, preferably before the meeting at Cooperstown, where the papers will be presented on Wednesday morning, June 25. It is the desire of the Committee to know whether, in the opinion of engineers, any one of these specifications is desirable as a " model " or " skeleton " specification, and if not, to know what changes or modifications should be made.

A paper to be presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 25, 1913.

(*Subject to final revision for the Transactions.*)

(1) SUGGESTED SPECIFICATIONS FOR TESTING HIGH-VOLTAGE SUSPENSION INSULATORS

BY F. W. PEEK, JR.

The insulators specified herein are to be of the link suspension type for use in a........ volt circuit. The dielectric must be homogeneous and symmetrical and not appreciably warped.

Surface of Dielectric:

The entire exposed surface of the dielectric must be smooth and uniform and impervious to moisture. The dielectric must be moisture-proof throughout, and in case a glaze is necessary on the surface it must be smooth, hard and firm, and uniformly applied. The dielectric surface of the insulators must be durable and unaffected by the weather, ozone, nitric acid, or nitric oxides and sudden change in temperatures over the atmospheric range.

The requirement for imperviousness shall be as follows:

The sample for test must not have a glazed surface, and the volume must be in the neighborhood of 2 cu. in. (30 cu. cm.). It must be dried at 120 deg. cent until weight is constant, and then immersed in water for 48 hours. The temperature of the water to be between 20 and 40 deg. cent. It is then removed from bath, surface water rubbed off with a cloth, and weighed. It must not have absorbed water to the extent of more than 0.25 per cent of its original weight.

Cement:

When cement is necessary in assembling the dielectric and metal parts, it must be strong and durable—not the weakest point—and should preferably be rendered impervious to moisture,

unaffected by changes in weather, ozone, nitric ozides, and sudden change in temperatures over the atmospheric range.

If the cement contains organic compounds, the flow point must be over 90 deg. cent.

Fragility:

Designs must be of rugged construction and so formed that there will be a minimum exposure of any fragile part to missiles from below.

Length of Complete String:

Total length of complete string of units including cable clamp should not be more than— ft. (—cm.), nor less than— ft. (—cm.)

General Design:

Practical considerations being equal, preference will be given to the design applying best scientific principles in regard to the dielectric circuit.

TESTS

Factory Test:

Every single disk or unit shall be tested for two minutes continuously with voltage held at 10 per cent below the arc-over point.

Three completely assembled samples of each type of insulator to be considered shall be subjected to the following tests, and the purchaser reserves the option to subject one out of every two hundred to the same tests.

Arc-Over Tests:

The complete insulator or assembled string shall have a sufficient number of disks in series so that while dry the arc-over potential (effective sine wave) shall not be less than three (3) times the operating voltage (between lines), and not less than 2½ times operating voltage when exposed to a spray at an angle of 45 deg., giving 0.2 in. (0.5 cm.) precipitation per minute.

While under the above rain test the insulator must be able to withstand a continuously applied potential of 2¼ times the operating voltage for five minutes. The specific resistance of the spray water must be between—and—ohms per cm. cube. These potentials shall be supplied by a 60-cycle testing set, giving approximately a sine wave.

Throughout these electrical tests the string of insulators is to be supported on a grounded metal arm, and the voltage is to be applied between this arm and a 6-ft. (2-m.) length of cable

the same as is to be used on the transmission line. This cable is to be gripped firmly in a clamp, and project three ft. (1 m.) on each side. The potential shall be applied at not over half arc-over voltage, and increased at about the rate of 1000 volts per second.

Arc-Over String:

Arc-over should take place completely across the string and not from unit to unit in cascade. Preference will be given to the insulator which most closely fulfils this condition.

Corona:

At 1.3 times line voltage there must be absolutely no sign of corona or static discharge on either the insulators of the assembled string, or any of its fittings—other conditions being equal, preference will be given to the insulator for which the corona starting point is nearest the arc-over point.

Voltage Balance of String:

The ratio of the measured arc-over voltage of the string to *n* times the arc-over voltage of a single unit shall be determined. *n* is the required number of units in a string. Competitive tests must be made on the same transformer and generator at 60 cycles. Insulators are to be supported from grounded metal arm as above, and arc-over voltages measured on different string lengths, of from one to *n* units. Other conditions being equal, preference will be given to insulators showing best balance along the string.

If, in the opinion of the engineer, the "multigap effect" at high frequency on account of large metal parts or for other reasons, is probable, a special high-frequency string arc-over test may be called for.

Uniformity Test:

Twenty-two single disks or units taken at random from stock which have passed factory test, shall each in turn be placed in oil, potential not exceeding half arc-over voltage shall be applied, and gradually increased at about the rate of 1000 volts per second until puncture shall occur. Any twenty of these puncture voltage valves shall then be selected. The difference between the maximum and minimum puncture voltage must not be more than 20 per cent of the average voltage. The average puncture voltage must be not less than 30 per cent above the dry arc-over voltage.

Special Test

Impulse Test:[1]

Twenty-two units shall be selected at random. Each of these disks shall be connected in turn to impulse circuit shown in (Fig. 1). The gap *A* shall be set (60 cycles) at three times the arc-over voltage of a single unit. The voltage shall be increased until gap *A* arcs over, when the circuit shall be immediately opened by breaker. This shall comprise a " stroke." . . . . strokes shall be applied to each unit, or until puncture occurs. Preference shall be given to the insulator showing the greatest uniformity and the highest average puncture voltage. Referring to Fig. 1, the shunt condenser capacity shall be— microfarads, and the inductance—— millihenrys.

Note: The above test will show, in a general way, the probable effect of surges, lightning, etc., on the life of the insulator, as well as uniformity of the porcelain. The number of strokes,

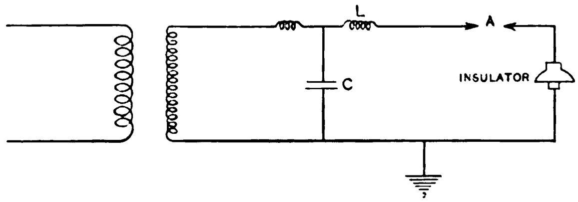

Fig. 1

and voltage to puncture will depend upon wave front of impulse, on frequency, etc. This cannot now be definitely specified, as the phenomena have not yet been sufficiently investigated. A test as above, however, is very important in competitive tests.

Method of Measurement:

Unless otherwise specified, the tests are to be carried on and voltages measured by the sphere gap, as proposed for the Standardization Rules of the American Institute of Electrical Engineers. The voltage shall be controlled in such a way as not to distort the wave form. It is preferred that it be controlled by a regulator consisting of a shunt resistance directly across the low-voltage side of the transformer, and a series resistance in the supply. The shunt resistance must always by-pass at least five (5) times the exciting current of the transformer. The

1. See *High Frequency Tests of Line Insulators*, by Imlay and Thomas, Proc. A. I. E. E., December, 1912, p. 2233.

principal control is effected by the series resistance. The method is often spoken of as a potentiometer method.

The sphere gap voltmeter must be corrected for temperature and barometric pressure. The arc-over voltage and corona starting voltage must refer to the average barometric pressure when the insulators are to be used and at a temperature of 25 deg. cent.

Mechanical Stress Tests:

After it has been decided from the electrical test how many disks shall constitute a suspension unit, this number shall be attached in a string together with the adopted suspension hook and cable clamp and a load[2] of —— lb. (——kg.) shall then be applied without rupture or signs of distress in any part of the string.

Mechanical Inspection:

A mechanical inspection shall be made of all insulators and those shall be rejected which contain open holes or cracks in the glaze or porcelain or are not perfectly cemented. The inspector shall use a light-weight mallet to rap each part and note the soundness of the ring. Occasional samples of the ware shall be broken to see that they do not contain air cells or foreign matter.

Protection of Metal Parts:

Metal parts must be made of non-corrodible metal or be heavily galvanized.

General

The insulator makers shall be required to furnish all facilities, equipment, and labor for making tests and inspection, as specified above, and shall at all times allow free access to such facilities and equipment by the authorized representatives of the purchaser until the entire order is inspected.

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2. Depending upon the size of the conductor to be used and the wind and ice load allowed.

(2) SUGGESTED SPECIFICATIONS FOR TESTING HIGH-VOLTAGE INSULATORS

BY J. A. SANDFORD, JR.

Specification for Suspension Type Insulators

General:

(a) These specifications are intended to cover the design, quality and manufacture, including inspection and testing, of ....porcelain insulators, cat. No.............

(b) The operating voltage will be........................

(c) There will be required approximately....................suspension insulators, each of which shall consist of........................units.

(d) There will be required approximately........................strain insulators, each of which shall consist of........................units.

Metal Parts:

All cap castings intended for cementing to the top of the porcelain parts shall be of the best grade of malleable iron. All studs or center pin forgings intended for cementing into the hole in the under side of the porcelain unit, shall be of the best grade of steel forging.

Galvanizing:

All cap castings and center pin forgings shall be galvanized by the hot dip process, and must be capable of standing the A. T. & T. four one minute immersion test. All fittings failing to meet this test shall be rejected.

See separate specifications covering galvanizing in detail.

Porcelain:

All insulators shall be made of a dense, homogeneous porcelain best adapted to high-tension insulator requirements, free from

injurious cracks and flaws or other injurious defects that would render them unfit for the purpose intended. The burning of all porcelain sections shall be done so as to insure thorough vitrification.

Glazing:

Unless otherwise specially agreed upon, the glazing will be brown and of a reasonable uniform shade, smooth, hard and continuous over all surfaces except those to be in contact with the cement.

Absorption:

Porcelain shall be practically non-absorbent. A test section broken from any insulator shall not show an absorption of more than one tenth of one per cent of its weight.

Electrical Tests before Assembly:

After inspection to eliminate faulty material, the unassembled porcelain disks shall be given a regular routine electrical test at a point just below flash-over potential for five minutes. If puncture occurs in the fifth minute, the tests must be continued until no puncture occurs in one full minute of test. All parts failing to meet this test shall be rejected.

Assembly:

All cemented joints between insulator parts shall be carefully made, using for this purpose the best grade of neat Portland cement, throughly mixed, and the proper stiffness for the nature of the work. The assembly shall be so done that no hollow or voids will be left between these cemented surfaces and all superfluous cement must be cleaned off of the insulator before crating.

Mechanical Test:

After approximately ten days' setting of the cement, all units shall be given the regular routine mechanical test of —— lb. (—kg.), with tension applied in line with the axis of the insulator.

Final Electrical Test:

All units shall be tested electrically to 95 per cent of flash-over for one minute.

Design Tests:

The dry arc-over value of the assembled insulator, consisting of——units, shall be not less than—— volts, potential applied for one minute.

The wet arc-over value of each insulator, consisting of —— units, and tested under standard precipitation of 1 in. (2.5 cm.)

fall in five minutes at an angle of 45 deg. with the horizontal, shall be not less than——volts.

At the option of the purchaser of his engineer, the contractor shall conduct tests to demonstrate the dry and wet flash-over values given above, but inasmuch as these tests are for proving correctness of design only, not more than five insulators of the same design shall be required to be subjected to the tests.

The average ultimate mechanical strength of the insulator shall be not less than 8000 lb. (3630 kg.).

At the option of the purchaser or his engineer, one tenth of one per cent of the number of units so covered by these specifications, may be tested to destruction, but only such units as are rejected for other causes shall be used in making this test.

Inspection:

The contractor will give to the purchaser or his representative such access to his works at all times during working hours as is reasonable and necessary to determine the suitability of material to be supplied, and shall furnish all necessary apparatus, labor, etc., in making the tests herein called for without cost to the purchaser.

All insulators are subject to final inspection, test and acceptance at contractor's pottery.

The inspection or waiving of inspection will not relieve the contractor from obligation to furnish material in accordance with specification.

Crating:

All insulators shall be assembled and packed one per crate ready for suspending from the towers. The crates will be of the contractor's standard design.

Should the contractor's design of crate not be satisfactory to the purchaser or his engineer or inspector, contractor will change same to suit the purchaser's requirements, with the reservation that at the contractor's discretion he may or may not still assume the responsibility for the safe transportation of the material affected by the change. Further, should the revised crate specified by the purchaser, his engineer or inspector, cost more than the contractor's standard crate, the difference shall be charged to the purchaser, which difference in accepting these specifications the purchaser agrees to pay.

Drawings:

Drawings showing detail of units and spacing of units in complete insulator are herewith submitted.

Specifications for Pin Type Insulators

General Information:

(a) These specifications are intended to cover the design, quality and manufacture, including inspection and testing, of ....porcelain insulators, cat. No.........................

(b) The operating voltage will be........................

(c) There will be required approximately........................insulators made up of........................parts, catalog No........................

Porcelain:

All insulators shall be made of a dense, homogeneous porcelain best adapted to high-tension insulator requirements, free from injurious cracks or flaws or other injurious defects that would render them unfit for the purpose intended. The burning of all porcelain sections shall be done so as to insure thorough vitrification.

Glazing:

Unless otherwise specially agreed upon, the glazing will be brown and of a reasonable uniform shade, smooth, hard and continuous over all surfaces except those to be in contact with the cement.

Absorption:

Porcelain shall be practically non-absorbent. A test section broken from any insulator shall not show an absorption of more than one tenth of one per cent of its weight.

Electrical Tests before Assembly:

After inspection to eliminate faulty material, the unassembled porcelain parts shall be given a regular routine electrical test as follows:

All parts of the insulator before being assembled will be tested for............ minutes at the voltages mentioned below. Should any part be punctured in the .... minute of test, the test will then be continued until no puncture occurs in one full minute of test. These tests are to be conducted by inverting the parts in pans of water and placing water inside the several pieces, the potential then being applied to the two quantities of water.

The voltages to be applied to the several insulator parts will be as follows:

Head..volts
Second shell.................................... "
Third shell...................................... "
Center... "

All parts failing to meet the above tests will be rejected.

Assembly:

All cemented joints between insulator parts shall be carefully made, using for this purpose the best grade of neat Portland cement, thoroughly mixed, and the proper stiffness for the nature of the work. The assembly shall be so done that no hollow or voids will be left between these cemented surfaces, and all superfluous cement must be cleaned off of the insulators before packing.

Final Electrical Test:

All complete assembled insulators shall be tested electrically at....................volts for three minutes. This test is to be applied in the same manner as the tests for parts described under "Routine Tests."

Design Tests:

The dry arc-over value of the assembled insulator, consisting of............parts, shall be not less than............volts, potential applied for one minute.

The wet arc-over value of each insulator, consisting of............ parts, and tested under standard precipitation of 1 in. (2.5 cm.) fall in five minutes at an angle of 45 deg. with the horizontal, shall be not less than............volts.

At the option of the purchaser or his engineer, the contractor shall conduct tests to demonstrate the dry and wet flash-over values given above, but inasmuch as these tests are for proving correctness of design only, not more than five insulators of the same design shall be required to be subjected to the tests.

Mechanical Test:

The insulators covered by the specifications must be capable of withstanding without signs of distress a pull of 2000 lb. (910 kg.) applied at the tie-wire groove in a direction at 90 deg. with the axis of the insulator and pin. For the purpose of making this test, the insulator shall be mounted on a solid steel pin turned from a piece of round steel of such dimensions that this piece of steel acting as a pin for the insulator will not bend under the above-mentioned load.

Inspection:

The contractor will give to the purchaser or his representative such access to his works at all times during working hours as is reasonable and necessary to determine the suitability of material to be supplied, and shall furnish all necessary apparatus, labor,

etc., in making the tests herein called for without cost to the purchaser.

All insulators are subject to final inspection, test and acceptance at contractor's pottery.

The inspection or waiving of inspection will not relieve the contractor from obligation to furnish material in accordance with the specifications.

Packing:

All insulators shall be assembled and packed in.......................... each containing.....................insulators. The.....................will be of the contractor's standard design.

Should the contractor's design of................ not be satisfactory to the purchaser or his engineer or inspector, the contractor will change same to suit the purchaser's requirements, with the reservation that at the contractor's discretion he may or may not still assume the responsibility for the same transportation of the material affected by the change. Further, should the revised.....................specified by the purchaser, his engineer or inspector, cost more than the contractor's standard.......................... the difference shall be charged to the purchaser, which difference in accepting these specifications the purchaser agrees to pay.

Drawings:

Drawings showing detail of the complete insulators covered by these specifications are herewith submitted.

Supplementary Directions and Explanations

Minimum Distance from Insulator to Grounded Objects:

As this factor does not enter into the commercial testing of insulators we recommend that it be neglected and the standard practise of the manufacturer accepted.

Number of Insulators to be Tested at one Time:

As there are several hundred sizes of porcelain parts to be tested we recommend that the number of parts under test at one time be such as to suit the manufacturer's convenience, except that the number shall not be so great as to take more than the full load current of the testing transformer, or make it impossible to hold the test voltage at the required point.

Factor of Safety—Dry:

We recommend that the dry flash-over voltage of any insulator be not less than three (3) times the normal voltage at which it is to operate.

Factor of Safety—Rain:

We recommend that the wet flash-over voltage of any insulator under standard precipitation of 1 in. (2.5 cm.) of water in five minutes directed at the insulator at an angle of 45 deg. with the horizontal, be not less than 175 per cent of the normal voltage at which it is to operate.

Quality of Water for Rain Test Purposes:

As this is one of the greatest, if not the greatest variable entering into the rain test, we recommend the use of condensed steam water. This can be easily obtained in any factory or laboratory. Pressure at 45 or 50 lb. (20-23 kg.) by means of an air pump completes an outfit that is satisfactory and the results obtained will be such that they will check very closely with those of other investigators.

Inasmuch as the results are comparative only, we feel that this is the best solution of the difficulty, even though the quality of the water may be slightly better than that met under operating conditions.

Angularity of Spray:

Standard practise has placed this at 45 deg. with the horizontal, the axis of the insulator being in the vertical postion. We see no reason for changing this practise.

Dew Test or Condensation of Steam on Insulator Surface:

We would recommend that this test be eliminated as giving no data that may not be obtained otherwise.

Testing Capacity of Equipment:

This is a matter of little importance so long as the number of insulators tested at one time does not load the transformer to more than its rated capacity, thus making it impossible to hold the voltage up to the required point, and may, therefore, be left to the manufacturer.

Method of Control of Voltage:

The method of using the field rheostat of the alternator as a means of control is offered as being the most desirable from all points of view. The low-tension winding of the testing transformer may be easily arranged so that for a given test voltage the generator may be worked at such a point on the saturation curve as not to cause any trouble from wave distortion, due to weak field excitation.

Control by means of an induction regulator taking current from a constant-potential circuit may also be recommended as

offering few objectionable features and as being very convenient in some instances.

Control by water rheostat in the primary circuit should be used only in cases especially arranged so that distortion of wave form will not occur or where much distortion will be unobjectionable.

The potentiometer method of control is well adapted to laboratory work where the number of tests to be made is comparatively small and the work is intermittent. For regular factory testing of insulators, however, this method is very expensive, due to the large amount of power being continuously expended in the resistances.

Grounding of One End or Middle of Testing Circuit:

As applying to all regular or routine tests this point may be left to the convenience or standard practise of the manufacturer. Special test or method of connection should be left for decision between the parties concerned.

Frequency of Test Voltage:

Any commercial frequency from 25 to 133 cycles, inclusive, may be used for regular factory routine tests. Special tests at frequencies not included above are to be covered by special specifications as occasion requires. This is intended to cover so-called " high-frequency or impulse tests."

Method of Measuring Voltage on Test Circuit:

The method of measuring the voltage on the test circuit shall be that method recommended by the American Institute of Electrical Engineers, covering such cases.

We suggest, however, that instead of taking spark gap readings for every test, the manufacturer calibrate his equipment, thus securing a curve between low voltage and spark gap readings which will be found to be sufficiently accurate for routine work and a very great time saver in making the tests.

What Constitutes Breakdown of an Insulator:

To the insulator manufacturer and probably the larger part of the engineering profession, " breakdown " of an insulator means failure by puncture, thereby totally destroying the usefulness of the insulator in question. We recommend that this term be understood in this sense.

Regarding corona, brush discharge, static streamers and arcovers we regard the conditions as different degrees of distress, and the manner of observing and recording them is open to discussion. The appearance of these various degrees of distress

is very irregular and uncertain and varies greatly on the same insulator with varying conditions of test.

The ultimate arc-over value of various styles of insulators may be obtained individually, but we recommend that the only way in which satisfactory comparisons of these other various degrees of distress on different styles of insulators can be made is to test all styles to be compared, at one time, in parallel, and in a dark room, when these differences can be seen and a fair record made.

Tests for the Puncture Strength of the Insulator:

Tests on a certain per cent of each 1000 insulators should be made to determine the ability of the insulator to resist puncture. This test is best made by submerging the insulator in oil. The nature of the test is such that it cannot well be specified to apply to more than a small percentage of the number of insulators covered by the specifications.

In testing suspension insulators under oil for puncture value, the porcelains should be completely assembled with the standard fittings, (or equivalent), with which they are to be used in service.

In the case of pin type insulators there should be attached, to the head of the insulator, wire representing the tie and line wires, and a metal pin should be assembled in proper manner in the pin hole.

The test voltage should then be applied to the fittings in each case. The average puncture value obtained under these conditions should not be less than 135 per cent of the dry flash-over voltage of the complete insulator in question.

In order to be able to compare results of tests made by different investigators, it is necessary to standardize the manner of applying the voltage as regards the time element involved. We recommend the following:

Apply to the insulator a voltage 20,000 volts below the dry flash-over value for 30 seconds, then raise the voltage by 10,000-volt steps until puncture occurs, holding the voltage constant at each step for 30 seconds.

For testing sample disks of porcelain not made up into insulator shape, we recommend that spheres ½ in. (12.7 mm.) in diameter be used as terminals.

Simultaneous Mechanical and Electrical Test:

We recommend that this test be eliminated from the list of commercial tests, as we feel that it is purely a laboratory proposition and that at best the results of such tests are very unreliable.

(3) INSULATOR TESTING SPECIFICATION FOR INSULATORS HAVING AN OPERATING VOLTAGE EXCEEDING 25,000 VOLTS

BY PERCY H. THOMAS

Introductory:

This specification gives the conditions of tests and inspections which are found best to secure reliable high-tension line insulators for use under the ordinary conditions of power transmission work. It is expected to serve as a skeleton or model specification and may be supplemented by such additional matters as may be appropriate for any particular case.

GENERAL SPECIFICATION COVERING ALL TYPES

1. (a) This specification is intended to cover the inspection and testing as to design, quality and manufacture, of .... porcelain insulators, cat.No..........................., of .... Company.

(b) The operating voltage is...........................

2. *Drawings:*

A dimensioned drawing shall be furnished showing the complete insulator and, if the insulators are built up or composed of a string of elements, showing also each element.

3. *Inspection:*

The maker will give to the purchaser or his representative such access to his works at all times during working hours as is reasonable and necessary to determine the suitability of material to be supplied, and shall furnish all necessary apparatus, labor, etc., in making the tests herein called for without cost to the purchaser.

All insulators are subject to final inspection, test and acceptance at maker's pottery.

The inspection or waiving of inspection will not relieve the maker from obligation to furnish material in accordance with this specification.

4. *Design:*

All insulators shall be designed to fail by flash-over and not by puncture.

Insulators shall be of robust construction and design so as not to be easily injured in handling.

The ultimate criterion of the merit of an insulator is its performance in service and the best practical measure thereof is its behavior under definite tests. However, as no practicable tests actually reproduce service conditions, for example in the matter of high-frequency voltage, criticism on theoretical grounds is valuable, and, other things being equal, preference should be given to the insulators most closely conforming to theoretically best designs.

Metal Parts

5. *Corrosion:*

All metal parts shall be of non-corrodible material or shall be galvanized in accordance with the specifications for galvanizing prescribed by the joint committee of the National Electric Light Association in its specification for overhead crossings of power lines above telephone and other low-voltage lines.

6. *Factor of Safety:*

Metal parts shall have a factor of safety of at least three over the maximum strain that they may receive in service, except that with pins for pin type insulators the factor may be reduced to two where a higher factor is impracticable.

Porcelain

7. *Quality:*

All porcelain parts shall be made dense and homogeneous as is best adapted to high-tension insulator requirements, free from injurious cracks and flaws or other defects that would render them unfit for use in insulators. The burning of all porcelain sections shall be done so as to insure thorough vitrification. The surface shall be smooth and uniform and moisture-proof.

8. *Glazing:*

The glazing shall be .... and of a reasonable uniform shade, smooth, hard and continuous over all surfaces except those to be in contact with the cement. It shall be unaffected by weather, ozone, nitric acid, nitric oxides, alkali dust, or sudden changes in temperature over the atmosphere range.

9. *Absorption:*

The requirement for imperviousness shall be as follows:

The sample for test must not have a glazed surface, and the volume must be in the neighborhood of 2 cu. in. (30 cu. cm.). It must be dried at 120 deg. cent. until weight is constant, and then immersed in water for 48 hours. The temperature of the water to be between 20 and 40 deg. cent. It is then removed from bath, surface water rubbed off with a cloth, and weighed. It must not have absorbed water to the extent of more than one-tenth of one per cent of its original weight.

Cement

10. *Assembling:*

All cemented joints between insulator parts shall be carefully made, using for this purpose the best grade of neat Portland cement, thoroughly mixed. The assembly shall be so done that no hollows or voids will be left between the cemented surfaces and all superfluous cement must be cleaned off of the insulator before crating.

Electrical Testing

11. *Wave Form:*

The wave form of the generator shall be true sine curve within the limits specified for generators by the Standardization Rules of the American Institute of Electrical Engineers.

12. *Control of Voltage:*

The voltage shall be controlled in a way not to distort the wave form. It is preferred that it be controlled by a regulator consisting of a shunt resistance connected directly across the low-voltage side of the transformer, and a series resistance in the supply. The shunt resistance must always by-pass at least five (5) times the exciting current of the transformer. The principal control is effected by the series resistance. The method is often spoken of as a potentiometer method.

For routine tests other methods of variation of potential may be used, provided such routine test apparatus has been calibrated by an approved method for the actual parts or groups of

parts to be subjected to the routine test. Such calibration shall be made on the maximum numb r of pieces to be used in the routine test.

13. *Measurement of Voltage:*

The method of measuring the voltage on the test circuit shall be that method recommended by the American Institute of Electrical Engineers, covering such cases.

Fo routine work, instead of taking spark gap readings for every test, the maker may calibrate his equipment by the approved method of voltage measurement, thus securing a curve between primary voltage and secondary spark gap readings, which curve may be used to determine the secondary voltage. Such calibration shall be made on the routine test apparatus with the maximum number of parts to be actually used in the routine test.

14. *Kilowatt-Ampere Capacity of Testing Apparatus:*

The kilowatt-ampere capacity of the testing apparatus is important, for the leading current taken by the insulators tends to distort the test voltage. The maximum current taken from the test apparatus should not be so great as to distort the voltage wave sufficiently to cause a condenser to take more than .... times the current[1] it would take on a true sine voltage,[2] and the current taken from the test apparatus shall in no case exceed full rated load.

15. *Surrounding Conditions During Tests:*

With insulators intended for lines not exceeding 75,000 volts no object other than leads and support should approach nearer than 6 ft. (1.8 m.) to the insulator. For insulators intended for lines of higher voltages the conditions for the "design test" of complete insulators should be made as nearly as practicable the same as the conditions of actual service as regards the grounding of one side of the insulator and the arrangement and distance of grounded objects. A conductor of 6 ft. (1.8 m.) or more in length, extending equally on both sides of the clamp, should be used to represent the transmission wire.

Routine tests not being on completed insulators do not require these precautions, but in each case the method of making routine

1. See paper by C. M. Davis, A.I.E.E. PROC., February, 1913, page 237.

2. This may be determined by the formula $I = n\ V\ C$, where I is amperes, V is volts, n is cycles per second and C is capacity in microfarads.

tests shall be calibrated when the surroundings are different from those here prescribed.

16. *Frequency:*

Tests should be made at the frequency at which the insulator is to be used. Where special agreement is made tests must be made at 60 cycles on insulators intended for use on higher and lower frequencies. No error of a serious magnitude will be expected within the range of 25 to 133 cycles.

17. *What Constitutes a Breakdown:*

An insulator is said to "fail" under a voltage test whenever a puncture occurs in any part of the insulator or when a discharge of any sort passes from one terminal to the other, since such a discharge would be followed by an arc on a power line.

Local breakdown, either corona or local sparks, is an important symptom of weakness, and indicates possible bad performance under other conditions. The weight to be given local breakdown, however, is a matter of judgment and is best considered in the light of simultaneous competitive tests.

18. *Rain Tests:*

Water should be sprayed on the insulator at a uniform rate averaging 1 in. (2.5 cm.) depth in 5 minutes, and should be reasonably uniformly distributed over the whole insulator. The rate of precipitation shall be measured by collection of water in a pan at the location of the insulator, the insulator being removed. A satisfactory spray in the form of a fine mist can be obtained by some forms of atomizers where pressure is available.

The spray shall strike the insulator at an angle of approximately 45 deg.

The water used shall have a high specific resistance, not less than .... ohms per cu. in. (.................... ohms per cu. cm.). Pure water may often be obtained from condensed steam or melted ice, or rain.

When insulators are to be used in localities subjected to salt spray or alkali mists special tests should be made.

Oil Tests:

Tests on a certain percentage of each 1000 insulators, not exceeding $\frac{1}{4}$ of one per cent should be made to determine the ability of the insulator to resist puncture. This test is best made by submerging the insulator in oil.

Suspension insulators should be completely assembled with the standard fittings with which they are to be used in service.

With pin type insulators there should be attached to the head of the insulator, wires representing the tie and line wires, and a metal pin should be placed in proper manner in the pin hole.

The test voltage should then be applied to the fittings in each case. The puncture value obtained under these conditions should not be less than 135 per cent of the dry flash-over voltage.

In making the test, apply to the insulator a voltage 30 to 40 per cent below the dry flash-over value for 30 seconds, then raise the voltage by steps, until puncture occurs, at a rate of about 1000 volts per second.

PIN TYPE INSULATORS

19. *Inspection:*

All parts should be inspected before assembling.

20. *Electrical Tests Before Assembling:*

All parts of the insulator before being assembled will be tested for three minutes at the voltages given in the following table. Should any part be punctured in the last minute of test, the test will then be continued until no puncture occurs in one full minute of test. These tests are to be conducted by inverting the parts in pans of water and placing water inside the several pieces, the potential then being applied to the two bodies of water.

TEST OF VOLTAGES ON PARTS

Head..	volts
Second Shell................................	"
Third shell.................................	"
Center......................................	"

21. *Final Electrical Tests:*

All complete assembled insulators shall be tested electrically at 10 per cent below the flash-over voltage for three minutes. This test is to be applied in the same manner as the tests for parts described for Routine Tests, §§12, 13 and 15.

22. *Design Tests—Mechanical:*

The following design test shall be made on enough complete insulators, not exceeding $\frac{1}{4}$ of one per cent, to determine the behavior of the design and the uniformity of the product.

The insulators covered by these specifications must be capable of withstanding without signs of distress a pull of .... lb. (............ kg.) applied at the tie-wire groove in a direction at 90 deg. with the axis of the insulator and pin. For the purpose of making this test, the insulator shall be mounted on the pin to be

used in service. In case of failure the question as to whether the insulator or the pin is at fault shall be determined by testing again with a solid steel pin turned from a piece of round steel of such dimensions that this piece of steel acting as a pin for the insulator will not bend under the above-mentioned load.

23. *Design Tests—Electrical:*

The following design tests shall be made in enough complete insulators, not exceeding ¼ of one per cent, to determine the performance of the type. The insulator shall stand without failure:

A *dry arc-over* test of not less than three times potential between line wires applied for one minute.

A *wet arc-over* test of 2¼ times the potential between line wires for one minute.

SUSPENSION TYPE INSULATORS

24. *Inspection:*

All parts shall be inspected before assembling.

25. *Electrical Tests Before Assembling:*

The unassembled porcelain disks shall be given a regular routine electrical test at a voltage 10 per cent below flash-over potential for five minutes. If puncture occurs in the fifth minute, the tests must be continued until no puncture occurs in one full minute of test.

26. *Mechanical Test:*

After approximately ten days setting of the cement, all units shall be given the regular routine mechanical test of .... lb. (............ kg.), with tension applied in line with the axis of the insulator.

27. *Final Electrical Tests:*

All disks shall be tested at a voltage 10 per cent less than flash-over for two minutes. If puncture occurs during the last minute the test must be continued until no puncture occurs in one full minute of test. This test shall be made after the mechanical test above prescribed, §26.

28. *Design Tests—Electrical:*

The following design tests shall be made on enough complete assembled insulators, not exceeding ¼ of one per cent, to determine the performance of the type. The insulator shall stand without failure.

A *dry arc-over* test of the complete insulator, consisting of .... units, of .... volts, applied for one minute.

A *wet arc-over* test of each insulator, of .... volts.

It is preferable that the arc-over of the complete insulator shall be over the insulator as a whole and shall not be over the individual elements.

There is no advantage in a dry flash-over strength greatly exceeding the wet flash-over strength and there is the disadvantage of the greater danger of puncture. The wet flash-over voltage should not be less than twice the voltage between line wires.

29. *Design Tests—Mechanical:*

At the option of the purchaser or his engineer, one-tenth of one per cent of the whole number of assembled parts forming one element may be mechanically tested to destruction. Where practicable such units as are rejected for other causes shall be used in making this test.

APPENDIX

The following tests are recommended as desirable where appropriate. They are not incorporated in the above tests as experience with them is not yet sufficiently broad.

30. *Uniformity Test:*

Twenty-two single disks or elements taken at random from stock which have passed factory test, shall each in turn be placed in oil, potential not exceeding 30 to 40 per cent of arc-over voltage shall be applied, and gradually increased at about the rate of 1000 volts per second until puncture shall occur. Any twenty of these values of puncture voltage shall then be selected by the maker. The difference between the maximum and minimum puncture voltage must not be more than 20 per cent of the average voltage. This test should be repeated with one or more additional groups of 22 disks, not exceeding in the aggregate $\frac{1}{4}$ of one per cent of the total, enough to determine the uniformity of the product.

31. *Impulse Test:*

Twenty-two units shall be selected at random. Each of these disks, or preferably several disks in series, shall be connected in turn to the impulse circuit shown in Fig. 1. The gap *A* shall be set at three or p eferably four times the arc-over voltage of a single unit. The voltage shall be increased until gap *A* arcs over, when the circuit shall be immediately opened by breaker. This

shall comprise a "stroke." .... strokes shall be applied to each unit or string of units or until puncture occurs. Preference shall be given to the insulator showing the greatest uniformity and the highest average puncture voltage. Referring to Fig. 1, page 1646, the shunt condenser capacity shall be........... microfarads, and the inductance .... millihenrys.

NOTE: The above test will show, in a general way, the probable effect of surges, lightning, etc., on the life of the insulator, as well as uniformity of the porcelain. The number of strokes, and voltage, to puncture, will depend upon wave front of impulse, or frequency, etc. This cannot now be definitely specified, as the phenomena have not yet been sufficiently investigated. A test as above, however, is very important in competitive tests.

32. *Rain Tests—Position of Insulator:*

With pin insulators, where more convenient, instead of inclining the spray at 45 deg. with the insulator, the latter being vertical,—the spray may be made vertical and the insulator inclined at 45 deg.

An address presented at the 30th Annual Convention of the American Institute of Electrical Engineers, Cooperstown, N. Y., June 24, 1913.

SOME ASPECTS OF INSTITUTE AFFAIRS
President's Address

BY RALPH D. MERSHON

The address of the retiring President of the Institute has usually dealt with some subject more or less generally concerning engineering, or the engineer. It has been the exception, rather than the rule, that a presidential address has discussed Institute affairs. It seems to me eminently fitting and desirable that in retiring from office the President should record his views on the more important matters affecting the interests of the Institute, with which he has become acquainted as the result of his administration, and the years of service that preceded it. It is my purpose, therefore, to discuss some of the more important problems confronting the Institute, and record my views on them, and on some of the general conditions affecting the welfare of our organization.

All of us, I am sure, desire that the intensity and scope of the activities of the Institute shall continually increase. That new technical committees shall be instituted, as fast as the progress of the art of electrical engineering justifies them. That new Sections shall be formed. That Institute meetings, or Conventions, under the auspices of the Sections, shall be held whenever a Section desiring such a meeting can justify its authorization. In fact, that Institute affairs shall always be so conducted as to best conduce to the progress of the art with which our organization concerns itself. But there is a limitation on the degree of such activities, quite aside from the willingness of the individual members to give the time and energy necessary for them; the limitation imposed by the relation between income and expenditures. Take, for instance, the matter of technical com-

mittees. Whenever a new technical committee is formed it means added expense, principally for printing. It means, under our present method of procedure, that the matter resulting from the activities of the new committee will be issued to each of our 7500 members. It will be issued to each of them twice; once in the PROCEEDINGS and once in the TRANSACTIONS. The increased expense incident to the addition of a particularly active technical committee may, therefore, be quite a considerable item. It is evident that our activities, through technical committees, or otherwise, might be stimulated to a point where our income would not be sufficient to meet expenses. The Institute is approaching such a condition of affairs. The amount of our annual expense is uncomfortably near to that of our annual income. We must, in the near future, either slow down in the rate of increase of our activities, or cut down our expenses, or increase our income. We must either make our activities keep pace with our increase of membership, or decrease the expenses of our activities, or raise our dues. The last course would be highly objectionable, and the first highly undesirable. The second expedient, that of cutting down our expenses, is the only one that appeals to me. I believe it to be feasible, and I am sustained in this opinion by those of our members with whom I have discussed the subject.

Our largest single item of expense is printing. Undoubtedly we spend a good deal more for printing than is justified. From time to time we print papers and discussions whose proper medium is the technical journals, not the Institute publications. Our printing and mailing expenses can be considerably reduced by a more searchingly judicious selection of the matter for publication from the wealth of matter presented before the Institute. They can be much further reduced by devising some scheme whereby each member will receive only that matter which deals with the subjects in which he is interested, with the proviso that he can receive all the matter issued by paying something in addition to his regular annual dues. Possibly, also, we can avoid sending out the same matter twice. Undoubtedly there can be, and should be, devised some expedient, whether along the lines suggested or otherwise, that will be acceptable to the membership and will result in a saving which, for a time at least, will push forward the expense limitation upon the increase of our activities. The membership should assist the governing body in solving this problem.

This question of expense has a bearing, not always clearly appreciated, upon another matter. We often hear expressions of regret that other societies have been formed to deal with subjects presumably falling within the scope of the Institute. But I question whether this is always, or ever, a proper subject of regret. If a new society be formed, it draws from its members a certain income in addition to that these same members are paying into such other societies as they may be members of. It sends out its publications to its own limited number of members. If the new society had not been formed, if the Institute had taken up the work the new society covers with the same degree of intensity that the new society does, the Institute would have done this without any proportional increase of income, and would, under our present scheme, send the publication of the matter presented to all the Institute members, instead of the comparatively few of the new society. It is true that the expense *per member* of the Institute for issuing this matter would probably be less than in the new society, but it would not be enough less to counterbalance the fact that the Institute would have no proportionate increase of income, due to the new activity, and the fact that the published matter would be sent to all the Institute members instead of to the smaller number of the new society. It appears, then, that the new society accomplishes for the art of engineering, generally, two of the possible expedients mentioned above in connection with the Institute. That is, it increases the total income available for technical work, and keeps down the gross expense by sending published matter to those only who are interested in it. It would appear, therefore, that the splitting off of a new society from the Institute is not an unmixed evil. Perhaps there is, and in many cases I think there is, no evil in it at all. Of the members of the new society who are not members of the Institute also, few, if any, would have been members of the Institute if the new society had not been formed, and such additional members as might have been attracted to the Institute by reason of the new activity would not have yielded an increase of income comparable to the increased expense. On the other hand, the formation of the new society will draw away from the Institute few, if any, of its members.

Similar considerations apply to the question of amalgamating engineering societies, of which we hear from time to time. If engineering societies were brought together in a very general organization of the nature of a holding company, possibly some

considerable benefit might be derived therefrom. But if they were to be actually amalgamated into one society, I think it very questionable whether the disadvantages would not greatly outweigh the advantages of such a course.

For a good while there has been a tendency based upon tradition and precedent, to limit the scope of the Institute's work to those merely technical activities which some people seem to think constitute the sum and substance of engineering work. The attitude has been that the engineer is not concerned with dollars; that it is beneath his dignity to deal with them. This attitude has been maintained in the face of the fact that in all important practical engineering work the question of dollars is the very first one involved, whether it be in the construction cost of the work, in the operating expense in connection with it after it has been installed, in the profit to be derived from its operation, or all of these. I believe it is becoming more and more clearly realized that this old point of view is not only narrow, but erroneous; that a technical man is not an engineer unless he is an economist, and that he can not be an economist unless he can, and does, deal with the dollar side of every engineering proposition. This more enlightened point of view is being reflected in the work of the Institute, as is evidenced by the appointment of committees to deal with such things as depreciation, operating costs, etc. It is to be hoped that this tendency towards the liberalization of Institute activities will increase.

The system of local Sections, which has now been in operation in the Institute for ten years, has grown in importance and value, and will undoubtedly continue to do so as time goes on. I consider that some of the most valuable work the Institute is doing is being done because of the existence of the local Sections and I believe the importance and the value of the work done because of, and due to, the Sections will continually increase. I say this the more gladly because at its inception, and for some time afterwards, I took an unfavorable view of the Section movement, and had very grave doubts as to the possibility of the Sections ever amounting to much.

It has been suggested that the Sections be encouraged to make their organizations more formal than at the present time. That they have a system of technical committees corresponding to the technical committees of the national organization, insofar as the subjects with which the national committees deal are of interest in the part of the country in which the Section is located.

It has also been proposed that where a Section has a technical committee dealing with a given subject, the chairman of the committee shall be a member of the corresponding national committee. These suggestions are, it seems to me, worthy of very careful consideration. Their adoption would be a means of more closely binding together and correlating the technical work of the national body with that of the several Sections. I have, during the past year, endeavored to realize some of the advantages of such a scheme by appointing to committees men recommended thereto, at my request, by the Sections. The adoption of the suggested interlocking committee scheme would more or less automatically take care of the matter.

But whether the idea of similar technical committees be carried out to the extent suggested or not, it seems to me exceedingly desirable that each Section have a Membership Committee corresponding to the Membership Committee of the national organization. And that hereafter any effort made to acquire members be exercised, not by the Membership Committee of the national organization directly, but by that committee through the several membership committees of the Sections. It seems to me hardly in keeping with the dignity of the Institute to circularize for members. If each Section has a Membership Committee, these local committees will be in a position to campaign for new members, either by direct personal contact, or by enlisting the aid of other members of the Section, who, by personal contact and influence, can bring about the desired end much more effectively than it can be accomplished by means of circulars, and certainly in a manner much more compatible with the dignity of the Institute.

It is desirable that the membership generally take a greater interest in the conduct of Institute affairs, and participate in such conduct, so far as geographical location will permit. Many of the problems arising in connection with the work of the Institute can best be solved with the aid of our members, and they should not only be encouraged but expected to lend this aid. Such general participation would undoubtedly be facilitated if there were a better geographical representation on the Board of Directors than there has been in the past. While I realize that the greater number of the Directors must be drawn from sections of the country from which Institute headquarters are easily accessible, in order that the work of the governing body shall not be hampered, yet it would be desirable for a certain number

of the Vice-Presidents and Managers to be distributed over the remainder of the country. This could be done, without running the risk of seriously hampering the work of the governing body, if that body were increased by the number of the members to be apportioned to the districts more remote from headquarters. It seems to me that such increase and apportionment is desirable, not only as a means of participation, but as a means of recognition of effective service and achievement on the part of members distant from headquarters. Participation by the members in the conduct of Institute affairs would also be fostered by greater publicity in the matters coming before the Board of Directors. We obviously cannot expect the cooperation of our members, no matter how willing they may be to give of their time and effort, unless they know of the problems on which cooperation, advice, suggestion and criticism are desirable. There has been a tendency to take the attitude that it might be harmful to the Institute if matters on which there were differences of opinion in the Board of Directors became known to the membership. To my mind this is erroneous. I believe no live organization is hurt by discussion, no matter how general it may become. In fact the more open and general discussions are, the more likely is the organization to maintain a healthy condition. If there are vigorous differences of opinion, vigorously expressed, it is an evidence that the organization is alive, and if there be any contention, the more public it is made the more likely it is to be conducted in a spirit of the utmost fairness. For my part I should much prefer an organization live enough so that its affairs would evoke discussion, than one so dead that no discussion or contention would ever have place. Discussion, constructive criticism, even contention, when it involves matters of principle, are evidences of the vitality and worth-whileness of the organization, and not evidences of disintegration, or any tendency thereto. I believe it much better in every way for the Board of Directors to allow members to know of any considerable differences of opinion that may arise in the Board, than to endeavor to cover them up under the mistaken idea that harm to the Institute may result from their publicity. The Board should have nothing to fear from publicity. If it has anything to fear, that is all the more reason why the members should be apprised of the matter at issue.

Much of the opposition that is at times evidenced in new departures on the part of the Institute, and many of the criticisms

of current courses of procedure, are based on precedent and tradition. While I believe precedent should always be considered, I see no reason why it should not be promptly overruled if contrary to any course that on careful consideration appears advantageous and desirable. Precedent is, it seems to me, mainly valuable as causing us to more carefully consider a course proposed contrary to it, or as the basis for a decision in doubtful questions. The most striking and valuable improvements have almost always come as the result of action directly contrary to all precedent. The criteria of yesterday will not necessarily serve for today; and the criteria of today will probably not all serve tomorrow. There is no more reason why we should necessarily conform to the practise of others, or to our own practise in the past in Institute affairs, than there is in any of the other affairs of life. For instance, society is coming to see the futility and false modesty of endeavoring to blink certain physical facts in connection with human nature. It is coming to realize the false modesty and almost criminality of endeavoring to ignore those things which nature will not permit to be ignored except under penalty, and as a result, some matters are now openly discussed with a frankness that would have caused our forbears to hold up their hands in horror. There is no reason, that I can see, why in Institute affairs, any more than in the other affairs of life, we should hesitate to do those things that are obviously both fundamentally right and expedient, no matter what tradition may be outraged, or how contrary such course may be to previous custom and usage.

There have been criticisms of some of the present methods of conducting the affairs of the Institute which I think should be viewed in the light of what I have just said, rather than in the light of precedent. One of these is the matter of anything of the nature of competition for the offices in the gift of the Institute. To my mind a spirit of competition is to be welcomed rather than frowned upon. The offices of the Institute are no sinecure. The officials and others conducting the affairs of the Institute are directly responsible for the results obtained, and in order that effective results shall be forthcoming it is necessary that they devote a considerable amount of time and energy to the work their tenure of office implies. It is a matter of congratulation, therefore, it seems to me, that there should be competition for an opportunity to do hard work. It is evidence of the live condition of the Institute, and of its capability for accomplishing

results. To my mind it is a great deal better both for the Institute and the individual office holder that the latter attain his office as the result of his frankly evidencing his desire for it, and if necessary competing for it, rather than under the fiction, that no one believes, which would make it appear that he is prevailed upon to accept the office only through the urging of his friends.

There has been more or less objection to the circularizing which has sometimes been resorted to in connection with the election of officers; the idea being that it were better if the nominations were quietly made, by a more or less selected group of men, and the election conducted without any possibility of opposition. In other words, that, in effect, the officers of the Institute should be chosen by a selected few instead of by the membership at large. I have even less patience with this point of view than with that just cited. To put a ban upon circularizing would be to throw the power of nominating and electing into the hands of those who might be in a position to control these functions without the necessity of circularizing, by virtue of their ability to avail themselves of organizations outside the Institute, or by their control of organized cliques within the Institute. To forbid circularizing would absolutely tie the hands of those independent of any other organization, or of any clique, and would tend to put a premium on the control of the Institute by oligarchy.

There has at times been evidenced a tendency to elevate to the high offices of the Institute men who have done little, if any, work for the organization. To my mind this not only works an injustice upon those who have given the Institute their best efforts, but is against the best interests of the society in every way, especially if the individual's chief claim to prominence arises from activities in fields other than that of electrical engineering as defined by the Institute's constitution. One of the incentives to effort on the part of the individual members of the Institute is that of the possibility of recognition of such effort through appointment, or election, to some official, or semi-official, position. I am quite aware of the fact that in some quarters this is not admitted, and that such sentiments as this are taboo. But to convince himself that the statement I have made is a true one, one needs only to ask any individual who has labored faithfully for the Institute, whether in case it had been possible for him to have done the work accomplished without the remotest chance of his name ever being known in connection with the results attained, he would have been willing to labor as faithfully for

their attainment. In almost every case, if not every case, an honest answer will compel the statement that he would not.

It is the young man starting into his life work that we especially desire to attract to the Institute. Young men starting the struggle for existence have scant opportunity for devoting themselves to things other than those which will immediately forward their interests. Later on, when a certain amount of success has been achieved, they may indulge in the luxury of altruism, but until such measure of success has come to them they are neither justified in indulging in the kind of altruism that unrequited Institute work implies, nor are they willing to do so. It behooves us, therefore, to make service in the Institute as attractive to them as possible, and to this end we should so guard the offices of the Institute, elective and appointive, that they may be the reward, not only of achievement in electrical engineering, but also of service in the Institute. That the membership will feel that the criterion of fitness for these offices shall be not merely prominence, however great, but also a generous measure of previous effort in forwarding the interests of the Institute and the principles for which it stands.

Remarks similar to those I have made in regard to the Institute offices will apply to the question of membership in the Institute, and preservation of the highest standard for the various grades laid down in our constitution. In discussing the eligibility of candidates for membership whose qualifications do not seem to square with the requirements of our constitution, but who are prominent in some lines other than those covered by our constitutional requirements, those favoring the candidate often make statements as to his great ability and express their belief based thereon that he is entitled to membership. These people lose sight of the fact that the requirements for membership in the Institute are not a question of the opinion or belief of any individual. They lose sight of the fact that the requirements for membership have been agreed upon by the members of the Institute and are laid down in the constitution. The only opportunity, therefore, for opinion or judgment is as to whether the candidate meets these constitutional requirements. If the constitutional requirements are not what they should be, and if the membership comes to the conclusion that they should be other than they are, then they should be changed, but so long as they stand, they, and only they, should be the standard by which to measure eligibility.

I quite realize the fact that from the point of view of a few some of the things I have said not only are unorthodox, but border on heresy. I believe, however, that my views will be concurred in by a large majority of the membership. If they are not, then I cannot expect them to be of any effect or influence. If they are, I sincerely hope they may have an influence on the future course of Institute affairs.

DISCUSSION ON "TEMPERATURE AND ELECTRICAL INSULATION (STEINMETZ AND LAMME) AND "METHOD OF RATING ELECTRICAL APPARATUS" (MERRILL, POWELL AND ROBBINS). NEW YORK, FEBRUARY 26, 1913. (SEE PROCEEDINGS FOR FEBRUARY, 1913.)

(Subject to final revision for the Transactions.)

F. B. Crocker (by letter): The paper on "Method of Rating Electrical Apparatus" by Messrs. Merrill, Powell and Robbins, Sub-Committee on Rating, states that it is "recommended that no overloads be specified for apparatus except momentary overloads. Momentary overloads are defined as not exceeding 60 seconds" and are 150 per cent of normal rated torque or current.

This method is known as "Maximum Rating" or "Single Rating" in contradistinction to the present A. I. E. E. Standardization Rules, which require a definite overload capacity. In the case of a gas engine, maximum rating is not objectionable, in fact it is practically inevitable. Most electrical apparatus, however, is self-destructive as compared with a gas engine, which protects itself by stopping if its load is excessive. An electrical machine does not protect itself when overloaded; it exerts itself to carry increased loads until it reaches the point of self-destruction. The difference between electrical machinery and almost all other kinds is like the difference between children who want to study too hard and those who do not want to study enough. The former must be protected against themselves and require totally different treatment.

In practise it is impossible to predetermine the load of an electrical machine because it varies considerably and continually, with changes always taking place even when supposed to be constant. If a machine with no overload capacity is used to drive its rated load, the usual variations that occur are likely to be sufficient to injure it. If supplied with protective apparatus to safeguard it against overload, that same safeguard will prevent it from carrying the frequent and considerable variations in load occurring in practise. Those variations would make it necessary to adjust the safeguard at a point so much above the rating of the machine that it will be heated considerably beyond its normal temperature if it should carry, except momentarily, the load corresponding to this adjustment.

The basis assumed for maximum or single rating is briefly as follows: Fibrous (organic) insulating materials, as cotton, paper, etc., have a very long life provided that their ultimate temperatures never exceed 90 deg. cent. If, then, the temperature of the windings of a machine insulated with such a material does not exceed 90 deg. cent. when operating continuously, the maximum load at which it can so operate is taken as its rated load.

If, however, the machine has been running a sufficient time to bring its temperature up to 90 deg., any overload applied to it would heat the insulation beyond the safe temperature and

injure it. As already stated, no overloads are guaranteed on machines rated in this way. Beyond this point there is a disagreement between two groups of the advocates of single rating. One recommends that machines with such insulation should be rated to give an ultimate temperature at full load of 90 deg. The other group maintains that temperature rise, and not ultimate temperature, should be the basis for rating, so that a room temperature is assumed and deducted from 90 deg., the resulting temperature being the permissible rise.

The question is: What room temperature should be assumed? The temperature of ordinary rooms in which electrical machinery operates varies from 20 deg. to 40 deg. cent. The paper cited recommends " that 40 deg. be recognized as the upper normal limit of the cooling medium " or room temperature, which would make a standard of 50 deg. rise.

The ultimate temperature appears preferable because it eliminates the indefinite value of room temperature, but practically, the standardization of ultimate temperature would introduce confusion almost worse than no standard, because it would mean that before a sale could properly be made, investigation of the probable temperature of the customer's plant would be necessary and if one salesman estimated it at 25 deg. and another estimated it at 35 deg., the first would offer a generator for 65 deg. rise and the second salesman one for 55 deg. rise. The tendency would surely be to estimate the room temperature low, giving the customer as small a machine as possible, and endless trouble would result.

Moreover, any machine built in accordance with maximum rating must be applied to its work much more carefully than at present. Since it cannot carry any overload, it must never be overloaded, and therefore an intimate knowledge of the conditions under which each machine will have to operate, during its whole life, must be obtained. Even the most careful investigations can only go far enough to apply the motor properly in the first place, but they do not take care of future conditions. With single rating a machine would have to be rated at the maximum load it would ever be required to carry, and who is the prophet to predict what that might be? It could not safely be depended upon to carry unexpected or even peak overloads higher than its normal rating.

For example, suppose a manufacturer buys a motor to drive a lathe and tests are made when the lathe is performing its regular work to determine the power required, the motor being selected and applied accordingly. If the manufacturer should obtain tool steel capable of taking a larger cut from the material in process, the single-rated motor would be incapable of securing the advantage of this new kind of steel.

Consider also a motor applied to a line shaft driving a number of tools. The manufacturer finds it advisable to add one more tool. If a motor of maximum rating has been chosen on the basis that its name implies, he cannot add the tool because of lack of

capacity in his motor, whereas the present type of motor would carry such added load without difficulty.

If the line shaft gets a little out of alignment, which is very likely to occur, a motor of maximum rating would be incapable of meeting this new condition.

It is argued that single rating is safe provided the temperature limit is put low enough. The machine would have a margin for overload, although none would be guaranteed. This would not be satisfactory to the manufacturer because he would not get and would not be entitled to any credit for extra capacity not guaranteed. Nor would it be satisfactory to the customer because he is not informed as to the danger point. If we leave overload capacity in our machine, the customer will surely find it out and use it under unusual circumstances, hence we must inform him exactly what its limits are. If he is so informed, then we cease to have single rating and come around to practically the present basis of rating, which includes overload capacity.

Overload capacity is the margin corresponding to the *factor of safety* used in all branches of engineering. With maximum or single rating there is really no factor of safety at all. The two papers by the Sub-Committees on Revision of Rules and Rating both clearly accept 90 deg. cent. as the maximum ultimate temperature, measured by thermometer. This is the actual physical limit and it is merely an arbitrary matter if we subdivide it and call it the sum of 40 deg. room temperature and 50 deg. cent. rise. The paper by the Sub-Committee on Revision of Rules (February PROCEEDINGS, p. 119) allows for the fact that local spots or internal temperature will probably be about 100 deg. cent. at which the insulation defined above has "a comparatively long life." If, on the other hand, the maximum ultimate temperature of the *hottest* point does not exceed 90 deg. cent., then such insulation has "a very long life" (February PROCEEDINGS, p. 115, line 1). Hence with the rating proposed, which permits 90 deg. ultimate maximum temperature measured by thermometer on the *surface*, the temperature will actually be 100 deg. in the *interior*, certainly in spots. At this temperature the life of such insulation is considerably shortened. The proposed limit is therefore 10 deg. above the true safety point, which is that point at which any considerable deterioration begins to occur. This point for electrical insulation corresponds closely to the elastic limit of structural materials. It is this limit and not the actual breaking point that is taken as the basis in allowing a factor of safety. The point at which the electrical insulation breaks down corresponds to the breaking point of structural materials.

The proposed rating not only fails to provide any margin or factor of safety whatever, but permits insulation be be used at a temperature at which it admittedly suffers permanent and considerable depreciation. Hence the margin is actually a *negative*

quantity, and the factor of safety is less than one. Imagine a bridge that was "rated" in this way, its load being stated at more than its elastic limit. Of course with single rating this is the only figure mentioned, and most persons, either from ignorance, carelessness or something worse, would assume that to be what the bridge should actually carry.

An apparently good reason advanced for single rating is its simplicity. It sounds simple and therefore attractive, but it would be still simpler to have no standard at all. The purpose of a standard is to protect the public against ignorance and unscrupulousness, and the "single" standard would do neither. The purchaser would naturally assume that he could use a machine to carry the load at which it is rated. Certainly the seller would have every reason to allow him to think so. We are very far from the millennium when every customer will be so wise that he will correctly allow for a certain margin of capacity and when every salesman will conscientiously unbosom himself of all the limitations of the apparatus which he is endeavoring to sell.

As one who has always had a deep interest in the Standardization Rules of the Institute and who took part in their original formulation as well as both of their revisions, the writer firmly believes that electrical apparatus should not be single-rated. The manufacturer, the salesman, the purchaser and the user all need to be protected against their natural tendency, which is deep down in all of them, to take that rating as the proper actual load for the apparatus. Engineering is responsible for the introduction of proper factors of safety in the building of machines and structures. It is a violation of the fundamental principles of engineering and seems nothing short of foolhardy for electrical engineers to attempt to get along without factors of safety. Not only figuratively, but literally, it is Ajax defying the lightning!

James Burke: My understanding of the two papers is as follows: That the intention is to limit the ultimate temperature at which different kinds of insulation will be graded. The practise heretofore has been to have various temperature increases stated in the specifications. Some specifications are for 35 deg. increase, some for 40 deg. some for 50, some for 55, and some for higher increase. My understanding of the first papers is that independent of the increase in temperature, the paper intends to set an absolute limit so that if a temperature of the surrounding air is higher than 40 deg. the increase would be considered as a special case and set at a lower figure, and that the real intent of the paper is that it calls attention to the penalty of running at higher ultimate temperatures than specified in the paper. That determines the danger point from the user's standpoint.

Now, in order to apply that to commercial condition, it is necessary to agree upon a certain average of maximum air temperature for special purposes, and this paper suggests 40 deg. as the maximum which will permit of 50 deg. increase in tempera-

ture in machines with fibrous insulation as a standard commercial machine. As Mr. Lamme has pointed out, it is the ultimate temperature that determines the safety working point. But in the manufacture of machinery it is necessary to bring into consideration the increase in temperature, because on this condition the ratings of machines are determined.

I further understand that the intent of these papers is not to recommend that an increase of 50 deg. be standard, but that it be considered as a limit, so that if one wants to establish a lower temperature increase it is not inconsistent with this paper, it simply calls attention to the danger point, and that no temperature increases in excess of this should be considered good engineering practice, or should be recognized by the Institute.

On the suggestions of different ratings in the paper by Messrs. Merrill, Powell and Robins the intent seems to be to show six different kinds of ratings that may occur. The first is the continuous rating, which probably covers the majority of the machines today. That is classed as A 1, and then come five ratings that refer to highly specialized applications, not for motors that are usually sold under every day conditions, but in which the particular service has been carefully studied, the nature of the load, and the nature of the load variations, in order to employ entirely special motors for each instance. The A 2, A 3, B 1, B 2, B 3 have been suggested. My personal view is that they are suggested more for the purpose of bringing out discussion, although I am not posted on whether that is correct or not. The three A ratings relate to machines that reach an ultimate temperature. All the three curves show that the test is continued until a maximum temperature is reached. The A 1 is for a continuous load, constant load, the A 2 for a load that is on, and then entirely off for a period, and then on again, and then entirely off, and the A 3 for a load which varies between the maximum and minimum, and in which there is some load on all the time. The *B* ratings are in the same class as the *A* ratings, but for conditions in which the ultimate temperature is not reached, or, in other words, in which the service is such that the period of use is so short that the ultimate temperature is not reached, and that is the distinction between the two. I do not understand how it is to be determined what the equivalent test is. For continuous service, the equivalent test is a continuous test. For the A 2 class an 80 minute test is considered as an equivalent test, in getting the ultimate and final temperature for the service, which fluctuates between no-load and full load, or between out of service and in service. Now, that 80 minute test might be a proper equivalent for one condition of load, but it would certainly not be the equivalent for all A 2's. I would like to ask the authors of the paper to tell us how the temperature of equivalent tests would be determined for each kind of service.

The use of the initials of the Institute A. I. E. E. on the nameplates of machines, I think is intended to mean simply that the

temperature increase is not more than 50 deg., for fibrous insulation, and a higher temperature for other insulation, and also that the basis of rating is on the single rating or rating without overload, in other words the A. I. E. E. mark on the nameplate is a provision for 50 deg. increase and no overload. I do not think it is intended to mean that the A. I. E. E. approves of the A 2 rating being of the equivalent test of 20 minutes, or that there is any approval connected with that.

One very important point brought out in these papers is the matter of temperature correction, and I will say something on that subject after the papers on Temperature Correction are read.

Henry G. Stott: I wish to say one word in regard to the work of the Standards Committee. I think if you will review the past history of the Institute you will find that the present standing of the Institute work is largely due to the magnificent work and the unselfish support of the Standards Committee. I think it would be difficult to find a contract for electrical apparatus which has been drawn in the United States or in Canada in which you will not find the A. I. E. E. rules referred to as being part of that contract. I simply wish to convey my expression of appreciation to the Chairman and through him to the other members of the Standards Committee for the large amount of unselfish work they have done in helping along the Institute in this way.

Referring to the first paper by Dr. Steinmetz and Mr. Lamme, and coming to the curve Fig. 1, which applies to insulation of Class A, I would say that the results shown in this curve do not conform to my experience with this class of insulation. I have had some rather bitter experiences covering some fairly large machines, and it is my experience that four years more nearly represents the life of insulation of this kind than ten years under the conditions outlined. In one plant the machines were 3500 kw. in size, operating at 6500 volts. The temperature rise on the average was about 40 deg. cent., and the surrounding air was 30 to 35 deg. cent., making an ultimate temperature of 75 deg. cent. The life of those machines has averaged very nearly four years, and as a result we have now changed the insulation from Class A to Class B, in the endeavor to get a longer life from the machines.

In regard to the second paper on Methods of Rating Electrical Apparatus, I would like to suggest, referring to the proposed nameplates on the last page, that where the letters "h.p." occur there should be substituted "kw.," and then within brackets after that, in very small letters, should be stamped h.p., so as to make the important thing the kilowatts and the unimportant thing the horse power.

Leo Schuler: I have listened with great pleasure to what Dr. Steinmetz said in regard to the new Standardization Rules, especially that it is the intention to adjust them to the standardization rules of other countries. It was of special interest to

learn that you intend to do away with the overload capacities, which was hitherto the main difference between your rules and the German rules.

You know that the International Electrotechnical Commission appointed a special committee for the rating or standardization of machinery, which committee had a meeting in Zurich in January, and the conclusions of the committee with regard to the admissible temperatures were about the same as are proposed in Dr. Steinmetz's and Mr. Lamme's paper. It was also decided to state, not the rise in temperature but the absolute temperature, as the life of the insulation depends primarily upon its temperature. The limit adopted in Zurich for Class A (cotton, papers, etc.) was practically the same as proposed in the paper of Steinmetz and Lamme. That is, for impregnated cotton, we have stated that the temperature, if measured by the usual methods, should not be more than 90 deg. cent. For cotton, without impregnation, however, we have fixed the temperature at 80 deg. cent. only, because it seems quite certain that dry cotton without any impregnation will not stand mechanical stresses quite as well as impregnated cotton. However, for coils entirely impregnated with some compound so that all air is excluded, the heat conductivity is so much better than in an ordinary coil that the temperature gradient would be much less, and we therefore propose to adopt for such coils a temperature limit of 95 deg. cent. instead of 90 deg. This is, however, only proposed for continuous-current coils because in such coils the mechanical stresses are less than in coils for alternating current. The same limit should be adopted for coils which consist of only one layer of copper because necessarily the heat conductivity is much better than in ordinary coils, and the maximum temperature will be much nearer to the measured value.

Now, with regard to room temperatures, you propose to have a standard of 40 deg. cent. The International Commission has proposed 30 deg. cent. This is a great difference, of course. However, as is stated also in the paper by Steinmetz and Lamme, 40 deg. cent. will usually only occur in steam stations. Now, if we consider how many standard machines, especially motors, are used in ordinary rooms, and how many are used in steam stations—this will probably be one per cent or less—I do not think we should, therefore, introduce 40 deg. cent. as the normal air temperature for all standard machinery. Thirty deg. cent. will be quite sufficient, and even when in hot summer days 40 deg. occurs occasionally this would not have much influence on the life of the machine.

I should like to raise another question. If the curve Fig. 1 in Dr. Steinmetz's paper, for cotton in air, is assumed to be correct, there will be another somewhat lower curve for cotton in oil, as the deterioration of the cotton is due to the combined influence of heat and oxygen. We have in Germany estimated that the difference will be about 10 deg. cent., and, therefore, we

will allow 100 deg. cent. for oil transformers. Perhaps the authors of the paper will give their opinion on that point.

I should like to ask what the authors mean by "resultant temperature" when the cooling of the machine is affected by both the air temperature and another cooling medium, either air taken from outside, or water. Does it mean the mean temperature? That would not be correct, because it depends upon the distribution of the cooling effect on the air and the other cooling medium. In the new German rules the corresponding paragraph is as follows: "If besides the water or artificial air cooling considerable cooling takes place by the surrounding air, then the 'temperature of the surrounding' will be considered the temperature the machine or transformer attains when working not excited under the influence of the cooling medium." That means an additional test is made with the water turned on, under no load, and no excitation on the transformer, and then the final temperature is measured.

In regard to the second paper, I may mention that we use only the continuous "rating or rating for a certain time," that time to be stated on the name-plate; we do not speak of intermittent rating, intermittent service, or anything of that kind. I think that it is an unnecessary complication to adopt two temperature limits for continuous and intermittent service. This is simply a question of choosing the correct size of motor for the conditions of service. It will be understood that a motor for intermittent service will occasionally attain a higher temperature than it attains when tested under its rated load and within the rated time. It comes to the same result whether we use for a given service a motor of say 2 h.p. of one hour's rating with 50 deg. rise, or the same motor rated 20 h.p. for 90 min., with 60 deg. rise. I may further mention that we have in Germany tried to standardize also the time for rating machinery; we have adopted the rating of 10, 30, 60 and 90 min., which will probably meet all practical conditions.

H. U. Hart: Those engaged in the design of generators of large capacity have known for a number of years that the temperatures in the middle of the core or coils were much higher than the temperatures indicated by thermometers placed on the outside of the iron or on the exposed portion of the coil. These interior temperatures have been measured by thermocouples or other means, and suitable insulation provided that will withstand the maximum temperatures.

The present rules of the A. I. E. E. for determining the temperatures on generators are inadequate, as they specify the temperatures to be taken by thermometers or by increase in resistance method of the windings. They make no mention of the maximum temperature available for the different types of insulation on the interior of the core of windings. Due to recent commercial development of a number of instruments to determine these maximum temperatures inside the slot, opera-

ting companies have been unduly alarmed by the temperatures obtained.

I have examined the armature coils on a large generator having Class B insulation, which consists principally of mica insulation used in combination with other binding material. The coils had been in continuous service, operating at temperatures in the slot of approximately 110 deg. cent. for seven years, and there was no apparent deteriorations.

We have recently developed an armature coil having no fibrous binding material, the coil containing only copper, mica and asbestos. This coil would probably come under Class C insulation. Sample test coils were heated for several months in an oven at 250 deg. cent., and there was no apparent deterioration.

While it may not be advisable at the present time to work at such high temperatures, still it is interesting to note that suitable insulation can be provided, having such a wide margin over the temperatures recommended in the above paper. It would appear that instead of specifying very low temperature rises, necessitating a very expensive machine, there would really be more margin in a generator, having a fairly high temperature rise in the interior of the slot and fire-proof insulation.

I believe the recommendations of Messrs. Steinmetz and Lamme for the maximum temperature allowable on types A and B insulation to be conservative, and I would be in favor of having their recommendations incorporated in the Standardization Rules of the A. I. E. E.

B. A. Behrend: I want to say a few words about the history of the labors of the Standards Committee as I remember them during the last fifteen years. A report prepared by the former Standards Committee, of which I was a member for almost ten years, embodied rules with which we are all familiar, because they have been with us for half a score of years, or more. It is absolutely necessary in formulating a new code to consider the effect which the former code has had on the electrical industry, and I want to run over the past in a few minutes to present to you that aspect of standardization.

The old rules were conceived as expressing, as nearly as the art knew it at the time, viz., fifteen years ago, the facts known to the designers of electrical machinery. It represented partly the knowledge of the time, and partly the knowledge of the past. In fact, the code has always standardized the past. If there is any lesson at all in history, the new code is going to do the same again, viz., it will standardize the past. If we wish to standardize at all we have to standardize the past, for the obvious reason that we do not know the future, for which we should endeavor to cast our rules. With the constant progress and constant changing of conditions, there is nothing more dangerous than a rigid standardization, and while I want to express my own personal appreciation for the excellent work that has been done

and which has been embodied in this large volume of papers, I cannot help but fear that the standardization report which is to be the outgrowth of so much valuable material will be a handicap again to the industry.

The old rules were of no assistance to the designing engineer, or the engineer in charge of manufacturing plants. They were mostly incomplete, misleading, and fallacious, and, with the authority of the A. I. E. E. impressed upon them, they have been extremely harmful. No amount of facts presented could break the baneful influence of these fallacious rules. For many years I waged a campaign before this Institute in papers in which I presented voluminous experimental data, in order to demonstrate that the old rules as to regulation were useless, in fact thoroughly wrong and misleading. The method of measuring temperature by thermometer I contended was fallacious. But nothing could be done—the rules existed, handicapping the industry, the engineer, and the designer.

In the papers before us many of the old faults are corrected as we see them today, but let me ask you, will the new methods take care of the conditions as they will arise in the future? It is likely that, two or three years hence, these rules, by that time embodied in a code, will be a detriment again; may they not hamper again the designing engineers as well as the users of electrical apparatus? I fear that, if these rules are drawn too rigidly, with too keen a desire to embrace all the facts as we see them today, you will make a great mistake which it will be very difficult for you to correct in the future. Single ratings, or maximum ratings, are all right, but it is a new departure which is bound to cause much confusion until conditions have adjusted themselves to them. Our experience with the old code has shown that ten years after a rule has been advocated it has been adopted. Legislation follows the past, like standardization. I think we should endeavor to anticipate the future rather than legislate for past conditions, and that is, I believe, the weakness of the new Standardization Rules, for whose adoption I shall plead in a very general form, but, in fact, in so general a form as adopted by the German society. Such general form has the same advantage as the wonderful description of creation in the first and second chapters of Genesis. This story conceived probably thirty-five hundred years ago, has been worded in such beautifully general terms that it has fitted any theory of creation from the date of the Chaldeans to the evolutionists of modern times. The Book of Genesis is couched in such poetic, general language, that it can be applied to all conditions at all times. The report of the Standards Committee will be most successful if it also is couched in similar language, so that future generations will say, " these men anticipated our conditions."

James M. Smith: It appears that there are three standards to be considered. Two of them are adopted standards, the third a proposed standard. The first standard is that adopted by

practise, and based on the experience of many years. The second is that adopted by the American Institute several years ago, but which has not been adopted by practise, and the third is the standard proposed in the paper by Messrs. Merrill, Powell and Robbins.

The standard of practise has a normal full load operating temperature that is conservative and safe even under severe conditions of operation or application. It permits overload capacities which are stated, and are, therefore, a protection to both customer and manufacturer.

The American Institute standard which has not been adopted in practise requires the measurement of temperature by resistance which has not proved satisfactory, and allows for temperatures 10 deg. higher than that adopted by standard practice. The present proposed standard not only suggests temperatures 10 deg. higher than the present standard of practise but does away with all overload guarantee excepting one of maximum torque capacity which is stated to be 50 per cent above full load torque. It is apparent that the present proposed standard is for the purpose of making our guarantees similar to those of European manufacturers. This is for two reasons:

First, because it is considered desirable to have a world-wide standard, and

Second, to enable manufacturers in this country to compete successfully with foreign manufacturers in the export field.

For universal adoption, the first thing to consider is what are the correct standards. The present American standards are conservative and produce machinery ample in capacity to meet all conditions of ordinary service. European standards are not likewise conservative, and machines built in accordance with them must be carefully applied to avoid undue depreciation.

If the American standard is changed to conform with the European, then American purchasers educated in our conservative methods of rating will suffer from incorrect conceptions of the new rating until years have elapsed and they become educated to the new close margin standard. In determining standards of rating for electrical machinery the prime consideration must be the adoption of standards which will produce machines that will best serve the customer. It is my opinion that the European standards are not those which will best serve our American customers. It is also my opinion that the American standards will serve European customers better than the present European standards. Therefore, if a universal standard is to be adopted, I believe that standard should be the American and not the European, that is, the machine should have conservative temperature ratings at full load, moderate overload capacities, with safe temperature ratings and high maximum torques for the peak load conditions which almost every machine must take care of occasionally.

In the paper by Messrs. Merrill, Powell and Robbins the ulti-

mate temperature is stated at 90 deg. In the paper by Messrs. Lamme and Steinmetz this is defined as being temperature measured either by thermometer or resistance, and it is recognized that the hot spot temperature may be 10 deg. higher, making the maximum temperature of the machine 100 to 105 deg., which by reference to the curves is above the charring point of fibrous insulation. Hence the machines are rated above the point of rapid deterioration, or, as stated by Prof. Crocker in his discussion, they are rated above what corresponds to elastic limit and the breaking down point is only 50 per cent higher. I am strongly opposed to the new standard, or reduction of standard, for the following reasons: It would result in the purchaser receiving a smaller, lighter, and less powerful machine than before, with the sanction of the Institute.

Since these papers were issued I made tests on certain standard motors, both alternating-current and direct-current, which show that they could be increased in their rating from 15 per cent to 25 per cent and still meet the proposed new standards. Electrical apparatus is none too good, with a tendency to over-work it, and for many years an active effort has been made to raise standards, to fix them so that when the layman buys a 100 h.p. machine he gets a large and heavy one. The proposed change would result in his receiving a smaller and lighter machine.

Schuyler Skaats Wheeler: My interest in keeping up, or if possible, raising the standards for apparatus in this country is so great that I am impelled to say a word or two about one of the subjects before the meeting today.

I am an enthusiast about standards, and about the work of our Standards Committee. I think it is simpler, and therefore right, to use a single rating for motors and generators, provided this is done under proper conditions. But as I see it, the particular method of applying the single rating which has been proposed, incidentally has the effect of lowering the standard; this I am very much opposed to. Electrical apparatus needs plenty of margin or the adherence to a high standard; it is delicate and liable, unlike almost every other kind of apparatus, to approach the breaking point without the fact being visible to the user. The first thing he knows it is gone. For that reason alone, if for no other, it is desirable that it should have plenty of margin.

We are in the habit of producing electrical machinery in this country which, besides the power that it is said to be able to give, continuously, can give a much greater power for a short time. Therefore, its real capacity is a little greater than is represented to the customer. I think this reserve, or, as Prof. Crocker has said, factor of safety, should be preserved. I think it is very important to keep up the margins or factors of safety. I have been writing and talking on this subject for 25 years. My strong feeling on this subject really has nothing to do with the question of single rating by itself. I think it is perhaps a good idea to

have a single rating, but let us provide a *lower temperature* for that single rating, as Prof. Crocker has suggested, so that the machine under the single rating for a given power has to be just as large as the machine furnished at the present time. This will entirely meet the objection that I have arisen to speak about.

I do not think we should in America make a smaller machine for a given power than we now do because the foreigners do. I think as Mr. Smith said, it would be better to try to induce the foreigners to come up to our standard.

I feel that this single standard will probably be put through, in any event, and, I do not think it worth while to make any great effort to stop it, as I think that would be useless. But I do want to go on record as to what my feeling is, so that later on I can call the attention of my friends to my position.

P. Torchio (by letter): The main criticism of the two Subcommittees' reports are that the classifications by Class *A* and Class *B* insulation with their subdivision in Class A-1, A-2, A-3, B-1, B-2 and B-3 is in my opinion too indefinite for every day interpretation by the average user of apparatus.

The second criticism is that the service ratings recommended by the Committee are impractical for a great class of users of electrical machinery, like the central stations. I think that in this respect the Committee has taken too narrow a point of view of the practical service requirements in making the service ratings. To recommend that " electrical apparatus be rated upon a basis of ultimate temperature and that no overloads be specified except momentary overloads not exceeding sixty seconds " is absolutely impractical for a class of apparatus, like substation transformers, transformers on network, synchronous, converters, motor-generator sets, etc.

The systems of generation and distribution have up to the present been generally laid out on the basis of providing apparatus sufficient to carry the normal load with some overload capacity to take care of any occasional burn-out of a machine on the same bus or in immediate proximity on the distributing network.

All of this class of apparatus must have a liberal overload capacity for more than sixty seconds and at least one or two hours.

On the other hand, the apparatus that is limited in maximum output, like turbines, can be rated for a maximum temperature without overload capacity as recommended by the Committee. I think that this rating is a logical one because the apparatus is self-protected against excessive overloads and can therefore be safely rated for the maximum output.

On the other hand, apparatus that is not so inherently protected against overloads must logically be rated on a more conservative basis. To make a constructive criticism of what this basis should be, I would recommend that the Sub-committee on ratings be asked to prepare a comparative statement giving the corresponding capacities of a specific line of apparatus,

like transformers, converters, motors, etc., giving the corresponding values of apparatus rated as at present with 35 deg. rise and 50 per cent overload for two or three hours, and the corresponding values of some apparatus on the new rating. By having this tabulated comparison one can then have a clear idea of what the recommendations of the Committee mean and so arrive at definite conclusions.

I am sorry that without this comparison between the present ratings and the recommended rating I cannot make an intelligent criticism of the new basis of standardization.

I would also recommend that additional information be submitted by the sub-committee on the Revision of Rules, giving the effect of vibration, moisture, etc. upon insulation as its reliability is not only dependent upon temperature but upon these other causes which should therefore be taken into consideration in arriving at the new standards.

Philip Torchio: I sent in a written communication in which I made criticism of these reports stating that the classifications of insulation, etc., are complicated and indefinite and that the single rating without overload is impractical except for apparatus that is inherently protected against overloads. I further pointed out that to make a constructive criticism of these reports they should be supplemented with a statement of how these recommendations compare with the present rating of machines.—In taking the above position in the matter I don't want it to be understood that I am opposed to the single rating, as I do favor it where it is practical. In fact the company I am connected with has been credited as having originated the single rating for turbo-generators, and I remember that in 1905 I wrote for my employers the first specifications for a single rating on turbines. This rating has since been quite generally adopted. In this instance the single rating is a logical one because the turbine is limited in its maximum output, and also its efficiency is good up to full output. When it comes, however, to transformers, synchronous converters, motor-generator sets, motors, etc., the same limitation does not hold true. For brevity I will not reiterate what has been said by previous speakers on this point.

You might say that the user can easily adjust himself to the new conditions by ordering large machines where overloads are required. However, I think that this would lead us into considerable misunderstandings and troubles. The present machines which have been built on specifications considerably more conservative than the present ratings of the A. I. E. E. have given and are giving considerable trouble. These troubles have been caused entirely by overheating in localized spots. There might have been a band that was put on to hold the windings of the armature which interfered with the proper ventilation, or there might have been faults of insulation, or the effect of moisture, dirt or vibration, or many other causes, but the fact stands out that machines running at probably 70 per cent of the proposed rating are giving trouble now.

We must give good service to users of electrical apparatus. It is to the interest of the entire electrical industry to do so. The central station, the manufacturer, the consulting engineer and everybody concerned with electricity is interested in giving good service.

I assume, as do some of the previous speakers, that the new specifications would make the machines smaller and not as liberal in design as the present rating. One of the previous speakers stated the contrary. If such is the case my argument falls, but if machines are going to be smaller than they are now, I don't think we are justified in making such a departure. I recognize that the manufacturers have to meet competition in their export trade, but that is not for us to discuss. I would emphasize the necessity of consulting with the users and the central stations by submitting the problem to them in a more emphatic way than it has been done; perhaps by a circular letter asking their views and criticism. This matter should particularly be submitted to organizations like the National Electric Light Association, the Association of Edison Illuminating Companies and the Street Railway Association, forwarding to these bodies the Committee's reports supplemented by the additional information which I previously suggested, that is, giving a comparison in parallel columns the equivalent ratings of machines rated under the present standards and the proposed standards.

M. G. Lloyd: A fundamental question in discussing ratings is as to just what the word "rating" is taken to mean and what distinction is to be made between "rating" and "capacity." The capacity of a machine is limited by its ultimate temperature and this depends upon a number of conditions, such as room temperature, power factor (when this is determined by the load), wave form (when this is determined outside of the apparatus itself, as in the transformer), etc. It has been pointed out by the Committee that ratings should be based on the ultimate temperature as the limiting condition in the case of most electrical machinery, but just what distinction should be made between the capacity of the machine under working conditions and its rating? Capacity is a variable quantity determined by conditions. Should a rating also be variable, or should it be a fixed quantity for a given machine? This question is not clear in the Committee reports, especially in report No. 2. There seem to be several references to a determination of rating by the conditions under which the apparatus is to be used, and not by inherent factors of design and construction.

My own idea is that rating should be a fixed thing for a machine. The rating should be expressed for a definite voltage and definite frequency and should represent the load which may be carried under given limitations and certain definite conditions, and this quantity will not necessarily mean the capacity of the machine under any working conditions but only under some standard condition. For instance, a temperature rise of

50 degrees seems to be favored, based upon a room temperature of 40 degrees. Forty degrees is higher than the ordinary working temperatures. Nevertheless, in that case the Committee seems to have made the distinction that the rating shall be based upon a standard condition rather than the working condition. Elsewhere in the report, however, this distinction is not clear, as, for instance, in the case of power factor. Consider an alternating-current generator whose capacity, as expressed in volt-amperes, is not a constant, but varies slightly with the power factor, due to the fact that you cannot always run the excitation up to the necessary point to get the same amperes from the machine that can be taken at high power factor. Should a machine of that kind be rated in terms of conditions under which it is to be used, or should it be rated in terms of a standard power factor? As to most of these points, like temperature and wave form, the implied meaning in the reports is to base the rating on standard conditions, but with regard to other features, like power factor, this does not seem to be the case.

Charles P. Steinmetz: I wish to state, first, that there is still some misapprehension regarding the purpose of this convention. The sub-committees have endeavored to gather all the information and data they could get together, but this is necessarily incomplete, and the convention was called, therefore, for the purpose of eliciting such additional data and information as may be available, and more particularly to reach those classes of engineers who could not be reached, due to the nature of things, by the members of the committee, and to obtain their ideas. The class of engineers referred to are, more particularly, the operating engineers and the consulting engineers. The designing engineers of the country, are grouped together, locally, in a number of centers, and therefore can be reached and have been reached, but the operating engineers as well as the consulting engineers are scattered all over the country, and their views and their experiences are just as important as those of the designing engineers, but it is more difficult to reach them, because, as a rule, they do not volunteer information, and there is no place where you can go and round up, to use that expression, a very large number of them, and therefore we anticipated by such a convention as this, by bringing the matter up for final discussion in the Institute, we would be able, at least to get a considerable number of operating and consulting engineers to give their views.

In regard to the question of temperature as the basis for rating, there are two misapprehensions. The first is to mistake single rating for maximum output rating. The single rating proposed is not necessarily maximum output rating, and, secondly, the single rating as proposed, is not necessarily a higher rating than the rating which was previously specified with our old capacity, but may be higher or lower, depending on conditions of apparatus. Now, what is the purpose of rating? An ideal specification is to say the apparatus shall operate for a long term

of years without self-destruction. That is the ideal specification. In practise, however, certain reference conditions, must be definitely stipulated. The room temperature must be limited to a certain maximum, perhaps 40 deg. and the maximum insulation temperature must be limited to a definite value, 100 deg., or 150 deg., respectively, according to the class of insulation employed. Then the specification of the apparatus is that that apparatus should run indefinitely, and should give a good life, for any room temperature up to 40 deg., under any conditions of operation where the maximum insulation temperature does not exceed 100 deg. cent. Now, you see that these two limitations immediately give you a definite power value. It is a definite value of output, which gives a maximum of 100 deg. cent rise in temperature at a maximum of 40 deg. temperature in room. Under any other condition you can take more power out of the apparatus or less power. What we propose then is, as single rating, to give the rating which the apparatus would have and the maximum output which it can carry at a room temperature not to exceed 40 deg., and with an insulation temperature not rising above 100 deg.

Now then, if you operate that apparatus at a lower room temperature than 40 deg. you can get a larger output. If you operate the apparatus for a short time only at 40 deg. room temperature, you can get a larger output, for time and temperature in insulation, as in many other things, are interchangeable.—It is not true without further qualification, to state that cellulose fibre carbonizes at 100 deg. cent., or 120 deg. cent. The carbonization temperature of self-destruction is a function of time, and the shorter time allows higher temperature. Now you will understand that what the present proposed single rating means is this; it gives a maximum of output which the apparatus can carry continuously at any room temperature up to 40 deg.

Let us compare that with the previous specification of the rating and overload margin. Under that specification you were no better off; the intended margin was not sufficiently definite. When buying a machine at the old rating, *i.e.*, at a certain rating with a certain overload guarantee, you knew much less what you could get from the machine than you will under the single rating. It has been said that the machine should have a safe margin of 25 per cent in output. That means, that if you know the machine must carry a certain load, you will buy a machine rated at that load. On the old basis you would buy a machine capable of carrying a 25 per cent greater load. If it should happen that the load is steady and you never have any overload, you merely have thrown away 25 per cent of the output of the machine, and have spent more money for the machine than was necessary. You have bought a larger machine than was necessary. If it should happen that the average load, equal to the rated load, should fluctuate up or down 10 per cent, then you still have an unnecessary margin of 15 per cent. If it should happen that your load varies

50 or 100 per cent, it means that your margin of 25 per cent is worthless and your machine will burn out. The margin means nothing, and you cannot say that you will buy a machine for that rated load and that it will be safe. What you must do when using the old rating is to say that the machine has a certain rating and has 25 per cent overload capacity. The maximum output required of it is a certain known value. The maximum output the machine can carry, is 25 per cent overload, and this is what you require the machine to carry. From this you must deduct 25 per cent in order to arrive at the normal rating of the machine which you require for your purpose. You can simplify things by leaving out that 25 per cent overload, which is not overload, and merely say the maximum output of the machine is so much, or your maximum load is so much, and therefore, you buy a machine rated at whatever you have to carry. You see that there is no difference in the one way of rating or the other one, with the exception that in the old way the Institute established 25 per cent overload as the average satisfactory margin. But wherever you do not need the margin you get too large a machine. Where you need a larger margin, as in the machines to which Mr. Torchio referred, the machines complained of, you burn out the machines, and the Institute rules are of no value. The new proposition is to throw on the customer the burden of determining the appropriate overload capacity to be provided in each case. At the present time the industry is far enough advanced for the operating engineer to know enough to select his own margin, to know that he must allow no margin in such a case as the steam turbine driven alternator, and that he must allow 50 per cent or 100 per cent margin or even more, in such cases as synchronous motors operating in substations. By the new method the purchaser can get a machine to suit the conditions of each case. This was not the case where we had a rating and allowed a standard uniform overload.

We propose to bring up here for discussion the proposition to go a step further than heretofore and merely give a single rating, and then say that from this single rating you have to subtract whatever margin your particular requirement may need, to arrive at the size of the machine adapted to the diversified conditions of the industry.

Henry G. Reist: I want to point out that probably we have become accustomed to rating machinery with large overloads, due to the long experience with the steam engine. A reciprocating steam engine always had large overload capacity. On the other hand, the gas engine, and the water wheel, and now the steam turbine, are rated practically at the maximum load. There is a reason for this. The steam engine works with the greatest economy at about the point at which it is rated. The overload capacity is not put there for possible overloads which might come on unexpectedly, but it is rated at the point where it gives the highest efficiency. The same holds true with the

water wheel, the gas engine and the steam turbine, they rate them at the points where they give approximately the best efficiency. We should rate electric motors so that they will have the best average efficiency. At the present time many electric motors are shamefully underloaded. Running them at an underload means that the customer pays more for his motor than he should pay, he has lower average efficiency, and with an induction motor lower power factor, which means a more expensive transmission line, greater losses on the line, and bigger machines on the other end. We had a definition given us this morning of what an engineer ought to be, or ought to do, and I might point out that one of the duties of an engineer is to get the most use out of a given amount of material and expense.

The reason, probably, why motors are used underloaded is because the customer hesitates to put a greater load on them than is designated on the name-plate. If his work requires 40 h.p. he will probably say, "I will make it safe, and get a 50-h.p. motor," and he will run it all the rest of his life at 40 h.p., and probably under that, and consequently he has poor efficiency and all the things I have just pointed out.

I was very much interested in the proposed ratings for motors, that is, continuous and various intermittent ratings. It occurs to me that the schedule proposed is rather complicated, and I like much better the one that, as suggested, has been adopted by the German engineers, simply giving the rating, based on a run of a certain length of time; that is, it might be 10 min. and 30, 60, 90, as has been adopted by the German societies, or it might be some uniform increase, which I would like a little better, such as, for instance, 10, 20, 30, 40, and double that, or equal values geometrically, between the length of time under which they are operated. From each of these ratings the consulting engineer can select the one that is most suited for his work, after he has definitely determined, as nearly as possible, what the work to be done is. It also seems to me then instead of giving them arbitrary letters and numbers as A 1 and A 2, and B 1 and B 2, they might simply use the length of time that the motor runs at its rated load as the name by which to know this particular rating. That would somewhat simplify the nomenclature, I think.

I just want to say one other word about the first paper, regarding the recommendation that we consider ultimate temperatures rather than rises. I must confess I am a little stupid on that point and do not quite see the difference, because it seems to me that, if we use an ultimate temperature, we must take some room temperature as a standard, and it is suggested that this be 40 deg., with which I entirely agree, and that the rise on top of that, which is recommended, is 50 deg., I believe, which, after all is a rise of 50 deg. I agree with Dr. Wheeler and several other gentlemen who have argued for conservatism. I question the advantage of going to too high temperatures in most cases.

There are exceptions, such as in the case of the railway motor, and probably in a good many other cases, but when it is not necessary, let us keep to low temperatures. The difference in cost of construction between the two machines is comparatively slight, whether we keep a little lower temperature or go to higher temperatures; and then, if you use mica or other material for external insulation, there is always the insulation between turns which becomes particularly difficult with the smaller apparatus, where it is difficult to put mica around each small wire of which the coil is composed. If the coil consists of a few conductors they may be taken care of, but when you have twenty to thirty, as we have in many cases, it becomes very difficult, and to me the only solution at the present time is to keep the temperature down. Some time we shall probably find insulations that will stand higher temperatures, but I do not feel that we have them for general use at the present time.

B. G. Lamme: I shall not undertake to discuss the arguments brought forward, but I wish to bring out more fully some points which seem to be very much misunderstood. There seems to be, in general, a wrong impression about the limiting temperatures which have been proposed, as some of the members appear to think that we are advocating raising the present temperature limits. On the contrary, we are proposing to cut them down. It is apparently believed that in adopting a temperature rise of 50 deg. cent. that we are insisting that apparatus be built for that temperature. However, what we actually said was that the temperature rise shall not exceed 50 deg. measured either by thermometer or resistance, *whichever gives the higher result.* We can keep as far below 50 as we please, depending upon what margin we wish to allow. We simply say that 50 deg. cent. rise shall not be exceeded, and that with the limiting air temperature of 40 deg. cent. the ultimate temperature of 100 deg. cent. in the hottest part shall not be exceeded. It should be understood, however, although it is not brought out sufficiently clearly in the committee papers, that the 10 deg. difference between the measureable temperature and the actual hottest part should apply only to ordinary low voltage insulations, such as 2200 volts and less. For relatively high voltages, with correspondingly thick insulations, a greater difference than 10 deg. cent. must be allowed between these temperatures.

In the present Institute rules, 50 deg. cent. rise by resistance is allowed, and on top of this, an overload of 15 deg. higher is allowed, giving a total permissible rise by resistance of 65 deg. cent. We claim that that is unsafe, except in those cases where the cooling air temperature is not over 25 deg. cent., for 65 deg. + 25 + 10 deg. internal drop = 100 deg. ultimate, which is the limit of safety. But taking air temperatures of 40 deg. cent., then 65 deg. + 40 deg. + 10 deg = 115 deg. ultimate, which we contend is unsafe. Therefore, we propose to cut out any conditions of the load which will put the ulti-

mate temperature above 100 deg. cent. However, it must be understood that temperatures above 100 deg. cent. simply shorten the life of the apparatus, and do not mean immediate destruction. This shortening of the life, in most cases, does not show up during the overload condition, as this usually represents but a small portion of the total operating period. The carbonization of the insulation, however, usually occurs on the peak load, and not under the normal operation. We therefore propose to cut out those conditions of temperature which are liable to have a material effect in shortening the life of the apparatus.

It has been mentioned several times that it is a maximum rating that we are proposing, and it is claimed that the proposed single rating and maximum rating are the same thing. However, it is not our intention to adopt a true maximum rating. I can possibly illustrate the difference by an example:

Assume a cooling air temperature of 40 deg. cent. and a rise on top of that of 50 deg. cent. and an internal temperature difference of 10 deg., giving 100 deg. ultimate. That fixes the limiting rating possible without exceeding the ultimate limit. This we call the single rating. But with cooling air at zero, with this single rating we still retain the 50 deg. rise, so that the ultimate temperatures becomes 60 deg., and not 100 deg. However, under this same condition, the machine could have a maximum rating corresponding to 90 deg. cent, rise instead of 50 deg., or the maximum rating, with air at zero, would be 80 per cent greater than the single rating which we are proposing. A machine could have all kinds of *maximum* ratings, depending upon the air conditions, whereas, they can have only one *single* rating, which is fixed in value by the conditions of air at 40 deg. cent. It seems to me that this confusion of the proposed single rating with maximum rating is back of much of the misunderstanding of the subject which has been expressed here this morning.

As the present Institute rules allow 50 deg. cent. rise under normal conditions, with 15 deg. higher temperature for overloads, and as the new method proposes 50 deg. rise as the highest permissible, it is obvious that, in fact, the machine, under this new method of rating could actually carry as much overload as under the old method, the only difference being that, under the new method, we recognize the danger in this overload, and call attention to it, and recommend against it, while in the old method, we went ahead and blindly guaranteed it. The new rules indicate a definite danger point, while the old rules did not. That is the principal difference between them.

Alexander Gray: In regard to the two papers presented this morning, there are several points about which I do not agree with the writers.

Much attention has been paid to the apparent fact that the limit of a machine is the temperature rise of the insulation. This may not always be the case, because the ordinary iron which we use is not non-aging iron. There is non-aging iron on the market,

iron in which the losses are small and do not increase with time, but that iron at present is rarely used for revolving machinery, because it is found that the losses are not reduced as much as would be expected, and also that such iron is liable to crack when subjected to long-continued vibration; it is well known that the long teeth of induction motors, when made with this iron, sometimes break off and damage the windings.

Regarding the temperature limit of 90 deg. which is suggested for Class A insulation, I consider it to be too high. Present practise calls for a temperature rise of 35 deg. cent. on full load, and 50 deg. cent. on 25 per cent overload, for two hours. Now, it is well known that 25 per cent overload at two hours on the top of a full load run is equivalent to 25 per cent overload continuously; that is to say, our present motors will carry 25 per cent overload continuously, with 50 deg. cent. rise, and will not deteriorate rapidly, but few designers would care to guarantee 50 deg. cent. rise, measured by conventional methods, when the motor is known to operate in a room with an air temperature of 40 deg. cent. I should suggest that, with Class A insulation, the upper limit, measured by conventional methods, should be put at 80 deg. instead of 90 deg. cent.

In discussing the second paper, the first point I would draw attention to is that all alternators should be rated in kv-a. and not in kw., even although the power factor be 100 per cent. There is a great deal of misunderstanding on this point at present. The Institute rules which we now have, state that a machine of 100 kw. output and 80 per cent power factor is a 100 kv-a. machine, whereas in practise such a machine would have a rating of 100 kw., but would have a kv-a. rating of 125. This point should be emphasized and made very clear in the new rules.

With regard to the rating of machines, we have, at present, continuous ratings, intermittent ratings, and short time ratings. Our subcommittee on rating suggests that this classification has not been carried out in sufficient detail, and now proposes to divide machines into two main classes, and six subdivisions in all. The large bulk of electrical apparatus is built for continuous duty, it being remembered that most machines, and particularly the copper in the machines, reach their final temperature in about two hours. That being the case, we have a comparatively small number of machines which are operating for less than two hours continuously, and these, it is proposed, shall be subdivided into five sub-classes. I consider that this matter has been carried too far and will lead to endless difficulty. I have asked several engineers in what class they would put a railway motor. Many of them said under the heading A 2, others, again, would put them in Class B 2. We can think of many other cases in which it would be exceedingly difficult to put the motor in its proper class.

In considering what I would suggest to take the place of these five classes, I looked over a paper published in the *Proceedings*

of the Institution of Electrical Engineers, by Dr. Pohl, and he suggests that for intermittent ratings an intermittency factor should be used: an intermittency factor of $\frac{1}{6}$ means that out of every six minutes the motor would be operating for one minute, and would be stationary for five minutes; a large number of applications, such as crane service, have perfectly definite intermittency factors. Now, a 50-h.p. motor with an intermittency factor of $\frac{1}{6}$ would operate at 50-h.p. for one minute out of every six and have an overload torque corresponding to a 50-h.p. machine, but if this machine be rated at 50 h.p. for half an hour, or at 100 h.p. for ten minutes, or at 40 h.p. continuously, what connection is there between the horse power rating and the overload capacity? The new suggestions are far from clear on this point.

With regard to bearings, considering that a large number of electrical machines, motors in particular, are in the hands of inexperienced operators, I do not believe it advisable for the Institute to recommend that bearings should fall into the general class of other materials, and have any temperature which will permit of safe and successful operation. Just as we specify temperatures in insulation, because the material gives no indication as to when it is going to break down, so in high-speed bearings, where there is no indication given that the bearing will seize, it is advisable in the interests of the public, who in the case of bearing breakdowns, will be charged with the use of poor oil, to limit the temperature of the oil in the bearings to 70 deg. cent., unless otherwise specified in some binding specification.

It must be remembered, finally, that it is not always the final temperature which limits a machine. The mechanical parts are built to suit a certain temperature rise, and if machines are designed for an air temperature of 40 deg. cent., then they will have considerable overload capacity with an air temperature of 25 deg. cent., but this overload capacity is not available unless the mechanical parts are sufficiently strong.

R. F. Schuchardt: In general I believe in a single rating, provided it is the continuous rating, and represents a safe margin. The other five ratings proposed in the paper of Messrs. Merrill, Powell and Robbins are undesirable for several reasons. First, we would have a number of different ratings for the indentical motor, which means in a central station for instance we would have to carry a large storeroom full of spares where otherwise a few would do, and the number of motors to be carried in stock would be multiplied greatly. The continuous ratings should also be given if it is desired to have any of these special ratings. Second, the proposed ratings would complicate rate-making, which is already a pretty complicated matter. The basis generally adopted for power rates contains a primary charge for the maximum demand. In motor installations the primary charge is usually based on the rated capacity of the motors. Now you can imagine what complications would be introduced in rate making by such a multiplicity of special motor ratings.

I do not agree with a preceding speaker regarding the use of the Institute symbol on nameplates. It would be a very grave error to put this symbol on apparatus, as it would be generally interpreted as putting the stamp of approval of the A. I. E. E. on the apparatus which bears the symbol.

There are two minor points which should be changed. In the paper by Messrs. Merrill, Powell and Robbins the statement is made: " Commutating apparatus should commutate not less than 150 per cent of the rated current." In railway machinery this should be " not less than 200 per cent."

In a succeeding paragraph the following statement is made: "All types of rotating machines should be so constructed that they will operate with safety at an overspread of 25 per cent above the maximum rated speed." Rotary converters, particularly, run away very fast, and the speed may increase at a tremendous rate, so that should read considerably higher than 25 per cent for the safe speed limit.

One word more, on the much discussed point of ultimate temperature. About five years ago we had an experience in a large central station in the West, during which we burned up a very large generator, and as a result of that we made some detailed investigations of the safe temperature limits for the insulation used on this particular class of apparatus. After we had carefully studied all of the test results we finally decided that 80 deg. is the maximum safe point below the knee of the heating curve which should be allowed, and that point determined by means of an exploring coil laid along side of the armature coils in the machine.

The paper of Messrs. Steinmetz and Lamme recognized the fact that there may be hot spots as much as 10 deg. higher than the measured temperature. We also assume that there might be hot spots even above this exploring coil measurement but we do not feel that it is safe to work on so close a margin as recommended in these papers.

C. E. Skinner: We have all been familiar for quite a while with the fact that the life of insulating material is a function of time, temperature and the mechanical conditions under which it is used. We have endeavored for a long time to find what is the ultimate upper temperature to which different classes of insulating material can be operated without getting into trouble. The German standardization of 80 deg. for cotton insulating material has been referred to. It is very rare, at this time, to find windings of electrical apparatus which are not treated in some way so as to bring them into the 90 deg. class as outlined by the Standards Committee.

J. M. Smith: There is one point which is not at all clear to me. It has been stated this morning that 90 deg. ultimate temperature was the hottest temperature in the machine. Mr. Lamme, both in his paper and his statement this afternoon recognizes that the hottest spot in a machine may be 10 deg. or

15 deg. higher than the ultimate temperature. This can be seen by reference to his paper. The difference between these two points of ultimate temperature is a difference of 10 deg. in the temperature rise, and it is the difference of between 15 per cent and 25 per cent in the capacity of the machine. I would very much like to have this important point cleared up.

B. G. Lamme: I wish to explain one little point wherein there seems to be some misunderstanding. It has been stated in the paper on " Temperature and Insulation " that a limit of 100 deg. to 105 deg. was allowed for fibrous insulations. I do not find any place where 105 deg. is either mentioned or indicated. Ten deg. to 15 deg. is mentioned as the possible internal drop, but the 15 deg. is tied up to 85 deg. This higher internal drop referred simply to cases where there was heavier insulation than in the ordinary moderate voltage machines. It was not brought out plainly enough in the paper that with very high voltage machines the internal drops should be considerably higher than indicated, possibly 20 deg. to 25 deg. Where 25 deg. internal drop is liable to be found, than, with fibrous insulations, 75 deg. measurable temperature would be the limit, and not 90 deg. It should always be borne in mind that where the ultimate temperature limit is fixed, the internal drop must be subtracted from this to give the measurable temperature, and this may be 90 deg. in some cases, while in other cases it may be 80 deg., or even 75 deg. depending upon the type of apparatus.

James Burke: If there is one point of more importance than another that has been brought out in these papers, I think it is the viewpoint which has been put on record that we have to recognize hot spots rather than any other temperature condition. I think a great deal of the discussion has been brought about due to the difference between the two papers. According to one paper, we can rate machines higher, according to the other we would have to rate them lower. So if we are discussing the paper of Dr. Steinmetz and Mr. Lamme, we can come to the conclusion that we may rate machines higher than the present commercial practise. If we discuss the paper by Messrs. Merrill, Powell and Robbins, we are in the class of conservatism which has been advocated by so many speakers here and previously.

In the paper by Dr. Steinmetz and Mr. Lamme they call attention to the fact that with fibrous insulation 100 deg. should be the maximum temperature, and then they assume 10 deg. for the difference between the maximum hot spot and the conventional measured temperature, and then come to the conclusion, when you measure temperatures by conventional methods, quoting their words, as follows: " The conventional methods of temperature measurement, as by resistance and by thermometer, do not usually give the maximum temperature, but give either the average or the outside surface values, and, when measuring the temperature by these methods, which are the only ones generally applicable, an allowance must be made in

windings for possible local higher temperatures." Now, if we consider that the 100 deg. hot spot recognized in that paper allows 10 deg. for some temperature gradient, leaving 90 deg. ultimate by conventional methods, with an air temperature of 40 deg., we have 50 deg. increase by conventional methods. That is the same as the existing rule of the Institute that has been in force for several years. It is not, however, in line with what the commercial practise has been. The commercial practise has been 40 deg. or in some cases 45 deg., so that if we compare the present commercial practice, of 40 deg. with this proposed 50 deg., we can rate our machines up, as Mr. Smith pointed out, from 15 to 25 per cent. I have made some similar tests and have found about the same conclusions. This comes from raising up the magnetic densities 12 per cent and the copper densities 12 per cent, and 12 per cent increase in current means approximately 25 per cent increase in copper loss and 25 per cent higher temperature, making a difference of from 40 to 50 deg. On that basis, if it is interpreted in that manner, we can rate machines up, and we are getting away from the direction of conservatism; but if we take the other paper, by Merrill, Powell and Robbins, we find that they advocate a maximum temperature of 90 deg. They say under the heading of " Temperature of Apparatus," as to ultimate temperature, the following, " a. Cotton, treated cloth, paper and similar substances which may fall in this general classification, a maximum ultimate temperature of 90 deg. cent." They evidently mean the hot spot temperature. The next thing is, how are we to determine that hot spot temperature. They do not say how it is to be determined, but they do say, " Temperature to be determined by approved method as may be specified in A. I. E. E. Rules." Now, then, the whole issue regarding temperature comes into that paragraph of what the A. I. E. E. Rules will be for determining the temperature. If the Institute Rules adopt a method that really gives the hot spot temperature, we will have lower conventional method temperatures than heretofore and more conservative.

We have among the papers to be presented at this convention one by Mr. R. B. Williamson, who shows one method of calculating the hot spots or the difference between the temperature of the laminations and the temperature of the surface of the coil, and he shows two tests, one his own, presumably with 19.5 deg. temperature gradient from the insulation, and quotes the test of some one else who shows 20.60 deg. In addition to that temperature gradient, there is another one from the outside of the coil to the inside of the coil, that is especially so if the coil is made up with round wires, with cotton insulation and air space between. So that with this temperature gradient assumed at 5 deg. added to Williamson's 20 deg., we would have 25 deg. of temperature to start with. That leaves us in the case of 100 deg. ultimate temperature, 75 deg. measured by the conventional methods, and deducting 40 deg. leaves 35 deg. increase.

This whole question of whether we are going to rate machinery up or rate it down depends entirely on what the Institute adopts in connection with this clause, "Temperature to be determined by approved method as may be specified in A. I. E. E. Rules." If we adopt the conventional 10 deg. temperature gradient, we are making a compromise. If we adopt a method of tabulating and calculating it for different thicknesses of insulating wall and different conditions, we are getting down to a more conservative rating. Difference of opinion seems to be on this point, and I think it will be determined one way or the other, depending on how these temperatures are to be determined. If the Institute adopts consistent rules for determining that temperature gradient to the inner part of the coil, the recommendations will be more conservative, and they will lead to the adoption of lower temperatures measured by conventional methods. I think if these few points are kept in mind we can come to a complete understanding, and find that every one is in accord on this subject of temperature. I think the sentiment of everybody is in the direction of more conservatism.

Charles P. Steinmetz: I wish to say that in both papers, in referring to the 90 deg. ultimate temperature, it is understood to refer to the temperature measured by thermometer or resistance. That is the average outside temperature, and not the temperature of hot spots which may be 10 deg. higher. Both papers recognize as the limiting permissible temperature rise, under extreme conditions, 50 deg. cent. Therefore, both are equally conservative or equally unconservative. However, I wish to draw your attention to one misunderstanding. There seems to be some idea that the new rule is less conservative in allowing 50 deg. temperature rise than was the former rule. As a matter of fact, it is more conservative, because the former A. I. E. E. specification allowed in electrical apparatus 50 deg. rise of temperature at rated loads, and in addition allowed 15 deg. more, or 65 deg. rise, at certain overloads for limited times. Now, in the new rules we do not permit the additional rise of 15 deg., because 65 deg. rise is not safe for all insulations and under all conditions. If the room temperature is 25 deg. cent., then you can have the additional 15 deg. rise, and still not exceed safe temperature limits even for Class *A* insulation. If your room temperature is 40 deg. cent., you cannot permit 65 deg. rise, as determined by conventional methods, without exceeding safety limits for Class *A* insulation. The only change which has been made from the old rules is that of leaving 50 deg. rise as the maximum standard rise. We no longer allow that additional 15 deg. Thus you see, we have really cut down the permissible excess rise above 50 deg., leaving, however, the 50 deg. as the standard which was recognized before.

I want to take issue with one statement, that 50 deg. was the *Institute* standard, but the *universal* standard was 40 deg. When we consider these lower temperatures, we always think of the

big, the important apparatus, the special high class machinery. That is all right, if we say that 50 deg. is the maximum permissible guaranteed rise, that does not exclude lower values but rather makes it desirable for us in this class of machines where we want to have extra-safe apparatus, and where we have big machines on which we can afford to spend some money to get good service conditions. There is no change from 40 deg. to 50 deg. Fifty deg. was the maximum permissible temperature. Thirty-five to 40 deg. may be specified and has been specified very largely, and will be specified in the future to suit special conditions, but there is a large mass of apparatus in which 50 deg. has been and is industrially used, and even higher temperatures, which we have to avoid and discriminate against. But the large mass of apparatus being built to-day, and which has been built in the past, has a 50 deg. rise, and we never think of it, because such small apparatus goes out in wholesale quantities. It is often put out by the smaller manufacturers and is good enough at 50 deg. rise, as good as is usually required. We have to recognize that this apparatus which is being manufactured wholesale is giving satisfactory service, and we cannot prescribe the standard for the best class of apparatus only, but we must have a standard to satisfy all conditions. It is not always realized that the A. I. E. E. specification while it gives the maximum permissible temperature, does not apply exclusively to the *best* construction, the *very best* class. You can get better than the rules provide, by specifying *lower* temperatures but you should not go *higher* than 50 deg. rise. If you stipulate specially low temperature you must be prepared to pay a higher price, and sometimes, as in large, valuable machinery, it will be good policy to pay the higher price, but for the vast majority of small machines, the 50 deg. rise basis represents approved practise.

C. J. Fechheimer: It is always well, when considering alterations, to profit by the experience of others. The single rating, 50 deg. standard has been the practise in Europe for a number of years and European electrical machinery has been used in Mexico and South America. In Europe the single rating method has possibly worked out fairly well, because there the operators are generally men of intelligence and education. Many station operators in Europe are University graduates. In Mexico, on the other hand, where the operators are less intelligent, the number of burn-outs with European machines has been more frequent than with American machines built on 40 deg. rise basis for normal load and with the usual 25 per cent overload. The 50 deg. single rating method puts the burden of proof for successful operation upon the operator.

The intelligence and education of the average operator in the United States is certainly less than that of the European although of a higher grade than that of the Mexican. Furthermore, the indications are that the class of help in American power stations, mills, factories, etc.—especially the latter two, where generators

and motors are used, will not improve. Therefore, if the single rating method is introduced, similar conditions will obtain in regard to burn-outs in this country to those which have existed in Mexico where European 50 deg. machines have been used. Even in the Commonwealth Edison Co., where a very intelligent staff is employed, machines have burnt out as pointed out by Mr. Schuchardt. What then may we expect with the higher rated 50 deg. machines, especially if overloaded as the average station operator is liable to do?

I wish to call attention to a statement of Mr. Reist to the effect that if machines were built in accordance with the single rating method, and the rating increased thereby, the efficiency would also be increased, since with our present system of rating, the point of maximum efficiency is higher at an overload than at normal load. I do not agree with this; in nearly all standard induction motors and commutating-pole direct-current machines the point of maximum efficiency occurs at a load lower than normal with our present system of rating. Although Mr. Reist's statement applies to the majority of alternating-current generators, the gain in efficiency by increasing the ratings of the alternators would usually result in an increase rather than in a decrease in the steam or water, etc. needed to operate the prime movers. Hence, from this point of view, the customer would lose rather than gain, if the ratings of all machines are increased.

Philip Torchio: The Committee recommends one rating for all apparatus. I state again that I have no objection to Mr. Merrill's rating of 90 deg. at hot spots for steam turbine generators and perhaps for waterwheel generators, but I think it would be a mistake to use the same standard for the class of apparatus referred to this morning, which is subject to overloads. For this latter class of apparatus I suggest 75 deg. maximum temperature. This would leave 15 deg. for possible overloading, though the amount of overload may not be specified. *I therefore recommend* 90 *deg. at hot spots for machines which are not subject to overload, and* 75 *deg. for machines subject to overload.*

B. G. Lamme: I think some confusion has come from the fact that the larger internal temperature gradients with high voltage machines have been overlooked. Mr. Torchio wants a temperature of 75 deg. on his high voltage machines. What he really wants is 75 deg. measurable temperature. What he is really after, although he possibly does not look on it that way, is to keep within the 100 deg. ultimate temperature, for the machines he has in mind have probably 20 deg. to 25 deg. internal drop, so that his 75 deg. measured temperature means probably 100 deg. at some point inside the machine. The sub-committee paper did not bring this point out clearly. We referred to 10 deg. to 15 deg. for low voltage machines, but Mr. Torchio is using, to a great extent, high voltage machines.

That also explains Mr. Stott's point. He referred to machines

which ran at about 40 deg. by thermometer measurement, with air temperature not over 35 deg. cent., which would make 75 deg. measured temperature, and he thought 100 deg. ultimate was unsafe. I know the type of machine to which he refers, and I think that there is fully 25 deg. internal gradient from the hottest spot to the point where he could make his temperature measurement, so that I believe his machines were at least 100 deg. cent., and possibly hotter at times.

Mr. Schuchardt suggests 80 deg. as the limit, but in his machines, if I am not mistaken, exploring coils outside the insulation were used in presumably what was considered the hottest part of the machine. His machines were also high voltage, and presumably there was at least 20 deg. internal drop, so that his machines also are probably close to the 100 deg. limit at the hottest part. I consider that all these cases cited are pretty good proofs of the ultimate limits which we have set.

B. A. Behrend: I think we should limit the total temperature of the hottest spot and leave it to the ingenuity of the purchaser or his consulting engineer to find that hottest spot. If you do not do that, you open all doors to that lack of conservatism which the consulting engineer and purchaser would deprecate. It is enough to say that, if you build a thousand machines, those thousand motors or generators are not all alike. If you give us leeway on the hottest spots, we will make the majority of them, say 900 machines, to meet a total temperature of 90 deg. and the remaining machines might exceed that temperature by 10, 15, or 20 deg., or by almost any other amount. That seems to me to prove conclusively that Mr. Torchio is right in demanding that the total temperature guaranteed should be the temperature of the hottest spot in the machine. This will make the manufacturer conservative. He is forced to turn out the majority of his machines at a temperature which will be below the total temperature guaranteed, because he knows very well that the iron is not uniform, and the core losses thus vary greatly, and are subject to workmanship, and therefore temperature rises may occur which he did not expect, and he must guard against such contingencies by guaranteeing the total temperature of the hottest part of the machine. There is no escape from this conclusion. If the manufacturer tries to evade this point, he is trying " to put it over " the customer.

C. P. Steinmetz: The ideal method, naturally, would be to specify that the maximum temperature, at 40 deg. room temperature, should not exceed 100 deg. cent., that is, to specify the temperature of the hottest spot. That is very nice and I have no doubt the electrical manufacturing industry would be glad to do that, providing the consulting engineers and operating engineers will tell them how to find the hottest spot. It is up to the Institute to make some standard rules, some specifications, which shall be so framed as to be *commercially* applicable. At present the only practical method of measuring the temperature is by

resistance or by the thermometer. Neither method discloses the temperature of the hottest spot. For many years people have imagined that these methods disclose the actual highest temperature, and that we have only 75 deg. or 80 deg. ultimate temperature in any part of the machine. Now, we know that these conventional methods did not disclose the highest temperature; that in cases where we believed the machine did not exceed 75 deg. at any part, there were interior parts which had temperatures of 100 deg. or more. The exploring coil shows temperatures a little nearer to the hot spot temperatures, but it does not show the temperature of the hottest spot anywhere in the insulation.

So you can see that the step in advance which we propose to take involves recognition of the hottest spot and limits the temperature of the hottest spot to not more than 100 deg. cent. But we cannot put that in any contract between manufacturer and customer because there are no means yet to determine the hottest spot, and so all specifications must still be based on the means now available for measuring temperature. This requires us to allow a lower conventional maximum temperature, say 90 deg. for Class *A* insulation. That is unavoidable. In short, we can *discuss* theoretical matters and the ideal conditions, but we *cannot meet* the ideal conditions in practise. That is the difficulty.

Now, what should be the limiting temperature for the hot spot? 100 deg. cent. has been advocated. Personally I believe that the hottest spot is safe at a higher temperature. Probably 100 to 105 deg. is quite safe, but we have no means yet of detecting the higher temperature, the hottest spot. And furthermore the whole question is complicated by the time factor. A temperature many degrees higher will occasion less deterioration *if only occurring during a few summer days*, than will a decidedly lower temperature *if continuously present*. We may say that if you take machines which are run hot, but do not burn out, which have been running for many years without trouble from heating, then the highest temperature which exists anywhere in one of those machines is the permissible hot spot temperature. But what is that highest temperature? Originally we imagined that that was what the thermometer and resistance methods of measurement showed. We have found, by getting more and more experience, that it is higher, and still climbing up, but I do not know whether we have, or have not, located the hot spots, and the fact is that the hottest spot is not a definite temperature which we can be sure of, but is the hottest spot in those machines which have been running for many years without burning out. I believe we are taking a step in advance to recognize this point, but we are not ready, and nobody is ready, to state what is the possible permissible maximum temperature for ordinary insulation which may be reached temporarily.

B. A. Behrend: If the hottest spot cannot be found, it is useless to say that its total temperature may be 100 deg. cent. If I cannot find it, I cannot guarantee its temperature.

C. P. Steinmetz: You may find it sometime—

B. A. Behrend: If I can find it sometime, then I like to know it and know its existence. I prefer to know that I am going to get a machine which will have parts hotter than those guaranteed.

C. P. Steinmetz: I mean that you will know it some time in the future.

B. A. Behrend: It is surely better to know beforehand than to find out afterward. Since we designers of electrical machinery appreciate that there exist hot spots, unless we admit their existence, we lead the people to think that our guaranty defines the hottest part of the machine. Let us admit the existence of concealed hot spots and guarantee a total temperature of 90 deg., and say that this refers to the hottest part of the machine. It will mean that ninety per cent. of all the machines turned out by the manufacturer will have a readily measurable total temperature of 80 deg. The purchaser will get the advantage of this, and it seems to me he is entitled to this advantage. Standardization must be for the benefit of both the manufacturers and the user, and therefore let the manufacturer be a little more generous in his dealings with the customer.

There is one point which I cannot pass over, viz., the adjustment of the efficiency to the power factor for a given rating. In neither steam engines, gas engines, induction motors, nor alternating current generators can we say that the maximum efficiency, the best regulation, or the highest power factor, are at the point indicated by its rating. The maximum rating of machinery places the burden on the user and his consulting engineer, and it seems to me that twenty years of education should have given the customer, if not the consulting engineer, an opportunity to learn how to make allowance for the conditions he has to meet. If a 50-h.p. motor is a 50 h.p. motor maximum rating, and if I am a little doubtful as to whether my plant requires 50 h.p. or 55 h.p., I shall take a larger motor. If I wish to use ordinary cable, or a piece of shafting, or a bearing, and consult a manufacturer's catalogue, I must apply the same reasoning. There can be therefore no objection to a single rating on this score. Why the electrical engineer alone should be less able to use his judgment than the mechanical or the civil engineer it is hard to see. When we design a bridge we must know the elastic limit of the materials used in it. The really important issue lies in the application of the designer's judgment to the safety factor to be employed.

I wish to say a word regarding the use of the emblem of the Institute on the nameplates. It creates the impression that the stamp of approval of the Institute has been placed on the manufacturer's apparatus, which we know is not so. It is not compatible with the dignity of the Institute. The single rating is a sound movement, and the only point to be decided is how to use it, or whether to deceive ourselves into believing that we have

cooler machines than we actually have. I do not approve of any species of make-believe. If I am to be robbed I want to know it; and if I am to be deceived, I want to know it also. If I have to use machines which will show a temperature rise of 115 deg. total rather than 90 deg., I want to know it. It is perfectly feasible to embody it in the same scheme now contemplated by the sub-committee.

R. F. Schuchardt: One more reference to finding the hot spots with regard to having the customer find them as suggested. It may be interesting to state more of the details of the experience mentioned in my previous discussion. At the time of the breakdown of this particular unit to which I referred, the temperatures were being taken according to the specifications in the contract, and the temperature limits of the contract had not been reached at the time of the breakdown. The customer then set about to find the hot spot, and with the permission of the manufacturer, put these exploring coils at the place where the designing engineers of the manufacturer said would likely be found the hottest spots. Then we made tests to find what is the safe maximum temperature to operate that insulation at, and we found this to be 80 deg.

Charles P. Steinmetz: If the designer or the manufacturer, or anybody else, only knew where the hottest spots are, and how to find them and measure them, the specification of the maximum temperature at the hottest spots would be the most satisfactory to the manufacturer, operating engineer, consulting engineer and everybody else. Unfortunately, that is not the case. We may *believe* that a certain region will be hotter, and even that it is the hottest place, but we do not *know* that with certainty. We know that the place which Mr. Schuchardt referred to just now was the hottest place which could be reached. Quite possibly somewhere else, at a place not reached by the exploring coil, there may be hotter spots, and that is the difficulty.

I sympathize with Mr. Behrend that he does not want to have something sold to him which is not as described, but if he will kindly follow the suggestion which we put forward at the beginning of the convention, not to make destructive criticisms but constructive criticism, and tell us how to go to work and locate the hot spots and how to measure them, he will be a great factor for good in the advancement of the electrical industry. But as long as we do not know how to find the hot spots with any certainty, or how to measure their temperature, we have to do the next best thing, and measure the temperature in ways practically available. I believe it is a step in advance to recognize the existence of the hot spots, to recognize that the measured temperature is not actually the maximum temperature, but that there is somewhere a higher temperature, and furthermore to recognize that the highest temperatures exceed the measured temperature by various amounts, (depending on the condition of the machine, on the design, on the insulation),

which exceed the measured temperature by 5 deg. or 10 deg. in some machines, like direct-current machines, or exceed the measured temperature by 20 deg. (or possibly even 30 deg.) in other machines, like those with high temperature, high voltage, heavily insulated, heavy armature coils. But we have reached something in recognizing that we want the assistance of all engineers to help us find where the highest temperatures are located and how to measure the highest temperatures. We will be glad to standardize the specification of the highest temperature and the methods to find it, if you can give us some feasible method of doing so.

W. L. Merrill: There is quite a lot of discussion on this ultimate and high temperature, and it must be remembered that it is only due to those cases in which the room temperatures are 40 deg., which is considered as the high limit of room temperature recognized by the Institute. Anything below that would be a factor of safety, which you would have in addition to these maximum temperatures. In taking up this paper, it was my understanding that the 90 deg. was to be the maximum ultimate temperature, as determined by methods approved by the Institute, either at present or in the future, whatever those rules should be. I think, perhaps, that would reconcile some of this discussion, and I would like to put in a hypothetical question—if there is a method determined, or if our present method, plus a correction which has been mentioned in the papers, were put into practise, what is the concensus of opinion of the various gentlemen who have just discussed these papers, or are interested in the subject, if the limit were put at 90 deg., if that would meet their approval, or rather, should it be 100 deg? In other words, is it 100 deg. that must be the maximum for fibrous insulation or 90 deg.?

There is one point I want to touch on—the question of bearings. The sub-committee thought it would be attacked a great deal more on the matter of bearings, perhaps, than some other things contained in its report. The question of limiting the temperature in the bearings of electrical machinery, to my mind is not very good practise. Is there any gentleman here who has purchased a steam engine and questioned the veracity of the manufacturer as to what the heating was to be in the steam engine bearing? Is not the same true with waterwheels? Is not the same true with line shafting, gas engines, or any other piece of machinery that is purchased, the question of bearing temperatures is not raised. I have a particular case in mind, which I think shows the fallacy of limiting the design of electrical machinery, we will say handicapping the design, by limiting the temperature of the bearings. In the case referred to vertical, waterwheel-driven units were used. At the time the engineering was done the waterwheel manufacturer was to supply the thrust bearings. They were put below the generators, and there was no reason to suppose the bearings were not all right to carry the load and give

a good account of themselves. By reason of later development, the man who was to install these units decided to have the bearings on top of the generators, so they now become part of the electrical equipment, and they had to be designed to meet the temperature rise of the Institute. It seems to me electrical machinery should be put in the class of other machinery when it comes to the question of bearings.

One more point in connection with the bearings—we will assume that we have a machine in which the engineer has decided on a 5-in. shaft with a 3 by 1 bearing, making a 15-in. bearing housing. The rubbing surface of that bearing is long, and it might heat beyond the temperature limit set down by the A.I.E.E. at the present time. That temperature can be materially lowered by shortening up the bearing housing. We could cut it down to a 5 by 10 bearing, and it is possible to still lower the temperature of the bearing, and the bearing is not as good for working as at that higher temperature limit. Another point was the rating of the temperature limits of the bearings at 50 deg. That is a physical impossiblity, although we are supposed to do it today. Take the case of a small totally enclosed motor, a mill motor or railway motor, where the temperature is practically uniform throughout the whole machine, the bearing must necessarily be approximately the temperature of the rest of the machine. On the rest of the machine we are allowed 75 deg. or 90 deg. rise, for non-fibrous insulation, and necessarily the bearing must go up to that, there is no help for it. I suggest, Mr. Chairman, that you get an expression of opinion from Mr. Torchio, and various other gentlemen who have discussed this paper, if their understanding is that the guarantees of the maximum hot spot should be 90 deg. instead of 100 deg., whether that would meet their objection.

Philip Torchio: In summing up the discussion, Mr. Chairman, I do not think you have taken cognizance of the point of view I have been trying to present. There is a serious objection to using the same limiting temperature of 85 or 90 deg. (which is required and allowable for turbo-generators) for that class of apparatus which is subject to overloads beyond the control of the operator or user. I want to emphasize the point that you cannot unify two distinct sets of conditions. You cannot have the same rating, the same maximum temperature for the turbo-generator and for the synchronous converter or the motor.

Charles P. Steinmetz: I wish to say that when considering the question whether 90 deg. or 100 deg. should be the temperature of the hot spots, we should give consideration to the present existing apparatus, to all those many small motors which are turned out by the thousands by many manufacturers, in most of which apparatus, with a room temperature of 40 deg. cent., the hottest spot is above 90 deg. cent. All of this apparatus would have to be redesigned, which would be a very serious matter, not to the big manufacturers, who could easily afford to do it,

but to the small manufacturers, who would have to redesign their motors and other machines to make them larger.

I would like to know whether the smaller manufacturers would be willing to rate down their apparatus, or to make them larger, and bring the limits of temperature to 90 deg., or less, maximum temperature, where it is now higher. It may not be higher by the conventional method of measuring, but undoubtedly most are higher, today, at 90 deg. maximum temperature, on the basis of 40 deg. room temperature.

W. H. Powell: The motor-generator set referred to by Mr. Torchio would be classified as A 3—Continued Pulsating Service, or under certain conditions as Class B-3—Short Time Pulsating Service. Other limitations prevail besides the ultimate temperature. The recommendation of the committee, viz., that apparatus be rated on the basis of ultimate temperature, and that no overloads be specified except momentary overloads, applies only to apparatus falling within Class A-1—Constant Service, where load is continuously applied.

Charles F. Scott: The fluctuating view points in this discussion raise the question, what do our Standardization Rules stand for? What is their purpose? What is standardization? Some things cannot be standardized in simple terms. For example, a few years ago the Standards Committee took up the rating of railway motors, which were given a " one hour rating " in our old rules. A sub-committee undertook a revision; meetings were held at which engineers from manufacturing and operating companies and consulting engineers to the number of some fifteen or twenty were present, some of them among the most prominent men in the Institute. The matter was discussed first one way and then another, and we kept getting further and further from a conclusion. We adjourned for a week. Then Mr. Armstrong came with diagrams and curves to show that the one hour rating was inadequate and that a certain method was better. Mr. Storer came with his data to show that something else was best. Everybody seemed to be conscience-stricken because we could not come to a conclusion, and tell how to rate railway motors in a simple sentence or paragraph, and the chairman suggested that we had better give it up, as agreement seemed impossible. A member suggested—" Maybe it is impossible, maybe the fact that the performance of a railway motor, which has to do so many kinds of service, cannot be expressed in terms which are simple, is the lesson we have learned in our discussion here." Each of those meetings started at four in the afternoon and ran to seven or eight in the evening, and the outcome was not to express the rating of a railway motor in two or three lines but to set forth methods of selecting a motor for given service in a couple of pages in an appendix to our present rules.

What are we now attempting to do with respect to the rating of motors? Are we not attempting to express in a few paragraphs the characteristics of all motors? The types of motors and the

conditions of service are so diverse that it is impossible to make simple classifications which will be adequate and complete. Stationary motors must meet a range of service conditions more extensive and more erratic than railway motors. The latter are fairly definite in type and in the nature of the service to be performed, and yet they do not admit of any simple method of rating; hence any elementary or simple classification of stationary motors must be rather general in its nature. In the proposed classification, there does not seem to be any discrimination between series motors and shunt motors, and the divisions of service conditions into several classes is only a first approximation, as can readily be seen if one selects several specific cases and endeavors to adapt them accurately to the proposed classification. If classifications were to include accurately all conditions, there would have to be a hundred or more divisions, instead of half a dozen.

What then do the Standardization Rules attempt to do? I have been a member of the committee for several years, and, speaking generally, our object has been to express what is good practise in definitions of terms and in methods of measurement. When, however, the Standardization Rules are used by the operating or designing or testing engineer, they are often regarded as something which should be absolute and complete, and the rules are criticised if they do not seem to meet definitely each particular case which may arise. The past policy seems to me to be indicated by this sentence in connection with transformer insulation tests: "The voltages and other conditions of test which are recommended have been determined as *reasonable and proper for the great majority of cases* and are proposed for general adoption, except when specific reasons make a modification desirable." In other words we are not making a set of specific rules, but we are giving sanction to practises which are good. It is expected that intelligent common sense will be used in applying the Standardization Code. We see, for example, that it is good practise not to have the temperature of a motor rise above a certain limit, but Mr. Merrill has just pointed out the absurdity in carrying this rule too far and making a bearing of one temperature if it is considered to be a part of a dynamo and another temperature if it happens to be considered as a part of the waterwheel.

We are discussing rating; what is rating? It is the assigning of certain values to express the capability of a machine. These values depend upon the quality of its materials, upon its regulation, insulation, temperature, and other factors. All these are indefinite; they may be expressed in curves. There are no definite absolute limits like the length of a yard-stick or the weight of a cubic inch of copper. The selection of the limits which fix the rating is a matter of judgment. Take, for example, a completed motor which has lost its name plate, and attempt to fix its rating and to determine the volts and amperes and speed

and horse power that should be put upon the name plate. Tests may be made, but judgment must be applied in selecting definite limits.

When a motor is sold, its name plate joins together two things —its past history in the factory, which determines its electrical capability, and the service it can render, which is its mechanical performance. The motor drives a shaft and the shaft drives the load. Torque and speed are the two things which the motor produces, and torque and speed are the things which the load requires. The requirements of the load are subject to definite variations in the relations of torque and speed and time. Our problem is to specify the capability of the motor in torque and speed and time in such a way that its adaptation to power service requirements can be determined. If we were to make classifications which covered all service requirements in point of variable load and time conditions, we would have a hundred classes, instead of the half dozen which have been proposed. Obviously, therefore, the motor classifications proposed are not complete and exhaustive, but they simply indicate what a motor can do under a few typical conditions. This must be supplemented by an intelligent comparison between the actual service requirements and the specified classifications.

What the motor specifications are accomplishing is to define, more definitely than has been done in the past, what a motor will do under several sets of conditions. The commercial engineer must then, with this larger knowledge of motors, make his selection of the proper motor for his specific case. We are assisting the seller and the buyer, not by covering definitely the various conditions of service, but by defining more completely the capability of the motor. We define what the motor can do under specified conditions, but we cannot define what it will be required to do in operating a lathe or a hoist or a pump.

The proposed specifications are general; they do not even distinguish between series and shunt motors. We simply lay a good general basis, and our rules cannot be extended much further, unless different types of motors are treated as we have already treated the railway motor by giving to each type an extended dissertation as to how the selection is to be made for each type of service.

Comfort A. Adams: There are two functions of rating; first, to enable the customer to compare the prices of different manufacturers; and second, to enable the customer, or his agent, the engineer, properly to choose a machine for a given duty or service. It is obviously impossible for any set of rating rules to cover all kinds of service. Those who have had to do with the choice of motors for a special purpose realize that there are hardly two cases which would be covered exactly by any simple system of rating. The important thing, then, is that we come to some agreement. It is not so important that the chosen temperature rise be absolutely safe at all times, as it is that we

understand what that temperature rise means. Just in so far as we know by experience or by computation, or both, what the difference is between the temperature of the hot spots and that measured by any particular method that we may agree upon, can we make intelligent use of the corresponding system of rating.

I do not agree that we must adapt our method of rating to the unintelligent unadvised customer who buys a machine on the basis of its h.p. rating, while guessing at the duty. That class of customer is a rapidly diminishing one, and should not be made the excuse for saying one thing and meaning another.

Charles F. Scott: What is the relation of the Institute to buyer and seller? We are a professional body and not a commercial body. It is our function to express what is good professionally. This was summed up in excellent form on the night of the original discussion which led to the formation of the Standards Committee, fifteen years and one month ago tonight, when Dr. Steinmetz said, that standardization came under two heads: first, a definition of terms, and second, a definition of methods of tests. We will do well to adhere to this scheme, doing professional work which directly concerns us and let the application to commercial work go to others.

Alexander M. Gray: In my previous remarks I attacked the clause on bearings, and I am still unconvinced on that point. Shaft bearings are in a different class from motor bearings; they squeak long before they break down, whereas a motor bearing gives no warning; and I still contend that the temperature of the oil in the bearings should be limited to 70 deg. cent. If the bearings are to be hotter, let us know about it, and put it in the specification.

I consider that Mr. Behrend is right in the attitude he takes about the use of the Institute initials on name-plates, but we should have something on the name-plate to show that the machines were given a single rating and not one with an overload capacity.

B. G. Lamme: I have been listening to many statements which are apparently in disagreement, and I will therefore try to do some averaging. It seems to me that many of the apparent discrepancies which have come up, are due to looking at the problem from a wrong basis. We all think of the temperatures of machines based on our everyday experience, but our everyday experience is really at 20 deg. or 25 deg. air temperature. On that basis we think of a machine which reaches 75 deg. cent. by measurement as a very safe machine. If, *at the same air temperature*, that machine is loaded until it reaches 90 deg. cent., we consider it is beyond the safety limits. That is correct, because, on the basis of 20 deg. or 25 deg. cooling air temperature, the machine showing 90 deg. temperature by measurement is an unsafe one in service, for such machine will probably be at least 100 deg. cent. at the hottest part, and therefore any increase in the cool-

ing air temperature puts the machine above the danger point. However, if the 90 deg. measured temperature is always tied up with the 40 deg. cooling air temperature, then the case is quite different, for at ordinary air temperatures, the machine then has only 80 deg. to 85 deg. ultimate temperature. In other words, when we think of 100 deg. as the ultimate limit with this proposed method of rating, we must always think of the 40 deg. air temperature in connection with it.

I also wish to emphasize one point, namely, that if the ultimate temperature limit is set at 90 deg. cent., instead of 100 deg. cent., that is, if 90 deg. is to be the hottest spot inside the machine, then on the basis of cooling air at 40 deg. cent., a vast majority of the apparatus now built in this country will not come inside the new rules, and this applies in particular to many lines of apparatus which are now thoroughly successful and have given satisfactory service in every way; that is, if we adopt a 90 deg. standard as proposed, then we cannot live up to it rigidly without derating a great deal of thoroughly satisfactory apparatus. This appears to me as one of the strongest arguments against the 90 deg. ultimate limit. If a rule or limit is set so that it will condemn thoroughly satisfactory apparatus, then the limit must be wrong.

C. L. de Muralt: Mr. Scott pointed out a moment ago that we are essentially a professional body. That is true, but we are a unique professional body. Many of our members are representatives of the manufacturers. Some may consider this as a difficulty. I do not look at it that way. I think that we can be greatly benefited by the presence of the manufacturers and by the work which they are doing to help us establish these standardization rules. Imagine a strictly professional body establishing standardization rules. It would be much more difficult.

We have really had three different views presented to us at this convention. We have heard the manufacturer say along what standard lines he is prepared to build his machinery and guarantee it. We have heard the operator state what he thought the manufacturer should do to help him buy machinery for special conditions. And we have heard the consulting engineer present his particular troubles in bringing the two together.

As a matter of fact, listening in the background, it seemed to me that all were pretty thoroughly agreed and I think we pretty nearly accept what Dr. Steinmetz and Mr. Lamme suggest to us. Two things must be considered in order to satisfy ourselves on machine rating. One is the maximum overload capacity. The other is how much of a load, continuous or intermittent, will the insulation stand? The maximum overload capacity, as I understand it, has not been touched upon at all in this report, nor has it been much mentioned today. In most cases it is a well defined point. We may, therefore, as well limit ourselves to the question of protecting the insulation. That means determining the temperature beyond which the insulation will

be damaged, and that is what I understand the sub-committee reported on. Most of the men who talked on this subject agreed that we want that temperature laid down definitely. Whether it be 90 deg. or 80 deg., or 100 deg. is possibly subject to further discussion, but I think most of us are satisfied that 90 deg. would be all right and we want the hottest point of any machine to be not in excess of 90 deg. if it is in touch with the insulation.

Then the only question remaining is the one brought up by the second paper, namely, how shall we make our ratings so that the above point is actually taken care of. Many of us have come to the conclusion that it is not well to have different ratings. It is safer to have the manufacturer rate his machines for running continuously, that is, for the worst possible operating condition from the point of reaching maximum temperature. Then, if a certain machine is to be run under different conditions, not continuously, then it is up to the man who buys that machine, or to his adviser, to find out how his particular run differs from the continuous run. This may reasonably be made the subject for another report by the Standards Committee, or possibly it may necessitate research investigation by an independent man presenting a paper, showing how certain specific runs or typical runs do make the temperature vary. Thus far it is not at all definitely laid down by anybody, and simply to anticipate a certain number of typical runs, that may or may not be met in actual practise, seems to me, and has apparently seemed to most of those who spoke on the matter, beside the point.

I maintain therefore that the outcome of this discussion is that the Standardization Rules should be on the basis of no point of any machines reaching a higher temperature than 90 deg. after a continuous run of sufficient duration to bring about maximum temperature.

H. M. Hobart: There have been intimations that the manufacturer had some object in this matter other than providing for the best interests of the industry. These intimations were not put forth strongly, but they have been repeated in several quarters. I have played different parts in the electrical industry, and I am now associated with a certain manufacturer, and I am satisfied there is absolutely no doubt about it, that the manufacturer has no greater concern than to get at the best results for the electrical industry. There is nothing altruistic in this standpoint; it resolves itself into a matter of enlightened concern for the interests of the shareholders. The manufacturer recognizes that it is a good investment to spend vast sums of money making investigations, and he thus secures special information which he gives freely to anybody who will take the trouble to read it—as I say he spends vast sums to get at these facts, and it has led his engineers to have certain views that such and such things are best. They have arrived at these views as the result of elaborate tests. If it can be shown that they are wrong, the manufacturer is willing to at once change his

plans. What the manufacturer wants is to promote the very best interests of the electrical industry as a whole, and he particularly wants definiteness in the matter of standards, some definite set of standards. That would be arrived at by this single rating system. If anyone has a necessity for using lower or higher temperatures, it is simply a matter of slide rule transference, for him to decide which size of machine he requires. The matter is far simpler than one would gather from the long, though very interesting, discussion which we have had about it.

B. A. Behrend: I feel constrained to say a word in regard to the remarks of Mr. de Muralt and Mr. Hobart. The relation of the manufacturer to this Institute is a question I do not intend to discuss. I do, however, wish to point out one thing, viz., that the manufacturer is responsible for the old code and for the last edition of our Standardization Rules, and that the application of these rules to actual conditions favors the manufacturer. For instance, the application of the rules to the determination of the regulation at 100 per cent power factor would give 4 per cent regulation, while in reality the regulation of the generator may be 8 per cent. I shall be satisfied with this single reference—which I made eleven years ago before this Institute while advocating the same system of determining regulation which you have now come to recommend. I do not charge, as Mr. Hobart's remarks would imply, and I do not wish to be understood as saying that the manufacturer has done this with an evil intent, as in the end he is responsible for results, and if he sends out poor machinery he must, and does, make it good.

Comfort A. Adams: It is absolutely impossible to devise a system of rating which will take account of all kinds of overloads. The safe limit of measurable temperature differs for different overloads, since the difference of temperature between the hot spot and the point at which the measurement is made is greater, in a given machine and with a given hot spot temperature, during the transient period of a short heavy overload than under steady conditions, owing to the heat capacity of the insulation. This is appreciable only in machines of comparatively high voltage and thick insulation.

A. E. Kennelly: It seems to be the consensus of opinion that a single rating for electrical machines is desirable, based on the maximum measured temperature attained. Differences of opinion enter as to just what that maximum measured temperature should be. It is generally admitted, however, that the maximum internal temperature of Class A insulation should be 100 deg. cent. That internal wall temperature is ordinarily inaccessible, and we must at present be content with measurements of the maximum temperature of the outside wall. The committee recommends 90 deg. cent., thus allowing 10 deg. cent. for drop of temperature in the wall. But whatever maximum measured temperature of the outside insulating wall is adopted between the limits, say of 80 deg. and 95 deg. cent., some allowance will have

to be made by electrical engineers in ordering large machines, for the special conditions under which those machines are to operate. A considerable number of machines may be ordered for continuous service at their nominal continuous rating under the new rule; but many machines will call for the exercise of reasonable judgment. If, for instance, a generator is to be ordered for a mill, in a cold climate, with the expectation that it shall have to deliver 1100 kw. and no more, for 10 hours a day, then a machine of perhaps 1000 kw. continuous rating might be sufficient; whereas if the generator were to be used in the tropics, with the expectation of delivering 1100 kw. ordinarily, but with occasional demands for 1500 kw., then a 1500-kw. machine might have to be ordered. Since, therefore, engineering judgment in the selection of a machine cannot be avoided on any basis of continuous rating, the exact value of the maximum measurable temperature is of secondary importance. The matter of primary importance is some one clearly defined maximum measured temperature to suit the average requirement, and then data from which the maximum internal temperature of the insulation can be predicted for large or special machines, from a given assigned schedule of load through the 24 hours.

A. M. Rossman: May I offer a suggestion which, I believe, is in conformity with the recommendations of the sub-committee on ratings, yet would meet the objections raised by several of the operating engineers. The suggestion is, that the recommendations of the sub-committee be adopted but that at the same time, a system of factors be established which would guide the purchaser in the selection of the proper size of machine for the class of service it is to perform.

For instance, in buying a new railway synchronous converter he would buy a machine 1.5 times the rating of his present machines provided his present machines were purchased on the basis of 50 per cent overload for two hours. In buying distributing transformers he would buy for the same duty transformers 1.25 times the rating of his present transformers. We are already used to turbo-generators rated for maximum continuous duty and these would therefore have a factor of 1.

I thoroughly believe in the system of single rating because (1) the manufacturer builds a machine to meet one definite temperature condition, (2) the consulting engineer bases his acceptance of the machine on a single temperature test, and (3) the purchaser has a common basis of comparison between machines of different manufacture.

C. E. Allen (by letter): The paper by Dr. Steinmetz and Mr. Lamme is of greater interest at this time than most of us realize, but it is the writer's opinion that there are a number of interesting phases of the subject which they have not touched upon. They state that the durability of insulation must be considered from two standpoints, *i.e.*—mechanical and electrical. I believe they should have stated three—the third being the "Method of Preparing and Applying."

As their paper is written more with a view of guiding the future than criticising the past, it seems just that they should have considered the improved insulation and methods of application in reaching a conclusion for the basis of a recommendation.

In order to understand more thoroughly the present and future methods, it is necessary to dwell somewhat on the past. Until very recently the methods of applying insulations in most of the classes of apparatus have necessitated the insulation being made in more or less of a flexible form, which has resulted in a larger amount of insulation being used than was actually necessary or desirable. By necessary I mean that the uniformity of the insulation could not be depended upon and that, in order to be sure of a pre-determined value, a greater amount was used, with the result that an occasional piece of apparatus out of the different classes could be selected which would show a much higher test voltage than it was actually designed for; yet as a complete line the average would probably not exceed the designed value. This increased amount of insulation also had its influence on the heating of the apparatus and resulted in a less uniform temperature and a greater maximum temperature of some one part of the apparatus. It was possible for this excess temperature to vary considerably in different pieces of apparatus of the same design and it was very possible for this temperature to be excessive and result in the short life of the insulation and resultant failure of the apparatus.

This past practise also permitted a defect to be taken advantage of in that where occasional pieces of apparatus would stand a higher test voltage than designed for, many times the electrical fraternity were led to believe that the insulation value of a certain line of apparatus, based on a test of one individual piece, was much greater than the actual average of the line, while the question of the excessive temperature as a result of this, which would have a decided influence in determining the life of the apparatus, was not fully taken into consideration.

The more modern methods of preparing and applying insulation, particularly where mica is used, have resulted in the insulation being formed into a proper shape and assembled with the apparatus in such a way as to eliminate any distortion of the same, which would otherwise be likely to result in a marked decrease in its insulating value. With these new methods, which also involve certain new elements in holding the mica together, it will not be necessary or desirable to use the excessive amount of material that has been used in the past.

While it may not be probable that one piece of apparatus out of a line can be selected that will stand as high a voltage as in the past, yet the average of the line can be depended upon, with a corresponding reduction in the maximum temperature. This will not necessarily mean, however, a lower average temperature, but a more uniform temperature, resulting in apparatus that will have a longer life.

The new form of insulation and method of application is also more durable from a mechanical standpoint and is not as readily injured by the contraction and expansion of the copper and iron in the apparatus where it is used.

While there is no question of a doubt that the later methods are a decided improvement and an advance over the older methods, yet it is going to be possible from comparative test, as formerly pointed out, to deceive a prospective purchaser and demonstrate to him, on the basis of one piece of apparatus, that the standard is not as high as it has been in the past. It is, therefore, very desirable that that part of the electrical fraternity representing the central stations, as well as that part representing the manufacturers, cooperate with the Institute committee and follow out its adopted standards.

When considering that this organization represents the foremost talent in the world, its recommendations should be taken verbatim and every central station and manufacturer should insist upon meeting only the A. I. E. E. standard, and not permit a higher value in one characteristic at the sacrifice of another. If this is followed out the result is going to be more satisfactory to the electrical fraternity as a whole.

E. A. Wagner (by letter): If we were able to build up electrical apparatus with homogeneous insulating material throughout, there would be no difficulty about classifying different electrical apparatus as outlined in the paper on "Temperature and Electrical Insulation." It seems to me that it would be decidedly difficult for anyone to determine whether some classes of apparatus would be Class A, B or C. This is particularly true of the proposed Class A and Class B apparatus. Take the case of generators in which the slot insulation is made up of mica or asbestos, or equivalent refractory materials. In these slots there are windings made up of the cotton covering which come under the Class A. An injury to the insulation between turns would put such a piece of apparatus out of business, yet would not necessarily communicate a ground to the core. The same thing holds true of certain makes of transformers. It might be argued that if there is any cotton present at all, then the apparatus belongs to Class A. If this is the case, then it would seem that the classification should be limited to two, one class which can burn out, another class which cannot, the latter class representing rheostats, heating elements, etc.

In the case of stationary transformers, the paper on rating loses sight of one important class of transformers which I think should be considered in the Standardization Rules. I refer to auto-transformers, sometimes called compensators. It has been the practice in some cases to rate these devices by the amount of the work transformed, considering this as the output. However in any device we must consider the output in kilovolt-amperes as the product of volts and amperes delivered at the terminals, without regard to the work of

transformation taking place inside of the case. It will, therefore, be seen that we have two. methods of rating such a device, and the practise has recently been adopted of rating these devices both in kilovolt-amperes transformed and kilovolt amperes output. I believe this method of rating provides for the classification of the apparatus, both from the standpoint of apparent work done and actual work done. One rating without the other can very readily be very misleading, and I think the Standards Committee should include a classification of this kind in the revision of the rules.

W. L. Waters (by letter): Probably the most important statement in Messrs. Steinmetz and Lamme's paper is that; " A blind adherence to some particular rule or method of taking temperatures may lead to fallacious results—and in the end it is the manufacturer who must supply the necessary margin over the approximate measurements, in order to make the machine safe," I think the committee would be ill advised to make, or to encourage the making of fixed rules at the present time for the measurement of internal temperatures in electrical machinery, as it is difficult even for the expert experimenters in the large manufacturing companies, who are giving their whole time to the work, to form an accurate idea of the distribution of temperature in a large machine.

Temperature tests are primarily to determine whether the insulation is operating at a dangerous temperature; but before this question becomes of any importance, it should be first known that the design of insulation, method of manufacture, and workmanship, are satisfactory. It has been known for thirty years that mica was a very good insulator for high temperatures, when it was used under conditions where its lack of mechanical strength was no disadvantage. It was also known that asbestos could be operated satisfactorily at high temperatures, but its lack of mechanical strength and hygroscopic nature rendered it almost useless as an insulator. The progress that has been made is in the development of processes for utilizing these high temperature insulation materials so that their material weaknesses are overcome; and also in educating workmen to be capable of carrying out these processes. It should be definitely recognized that on these points, the purchaser is almost entirely dependent upon the manufacturer, and that rules are of no assistance in passing upon them.

I would suggest that at the present time, the Standards Committee should state that it is extremely difficult to obtain any exact idea of these internal temperatures, though the purchaser would do well to satisfy himself that the manufacturer has provided insulation suitable for operation at the temperatures which exist, and further that the method of applying the insulation and the workmanship are satisfactory. I think that some such statement as this would warn the purchaser or operating engineer of the danger which may

be expected, and at the same time, will guard against the false feeling of security which frequently results after a few rough temperature tests have been made.

G. I. Stadeker (by letter): Although it is evident that a new system of ratings is highly desirable at the present time, it is advisable to make these changes slowly instead of confusing the vast number of buyers of power apparatus, who have but a slight technical training, by making several radical changes all at the same time.

The first step would be to change the method of rating as suggested in the paper under discussion by establishing the output on an ultimate temperature, instead of on a temperature rise, basis. But the suggested change, in rating of motors, from the horse power to the kilowatt basis would create considerable confusion. For instance, assume a motor-generator set, rated at 10 kw. This would ordinarily mean that the generator is 10 kw. There could be no misunderstanding in the present method of rating. But under the proposed system, a motor generator set could be rated at 10 kw. when the motor driving the set was rated at 10 kw., with the result that the generator itself could not have a capacity exceeding 8½ kw. or 9 kw. This is one possible source of confusion.

Another source of misunderstanding, if motors are rated in kilowatts instead of horse power, is that the general public would probably assume that a one kw. direct-current motor could be used as a generator to develop one kw. This would not be true. For instance, the ampere capacity of a 10 kw., 230 volt generator is 43.5 amperes. If this machine operated as a motor on a standard 230 volt circuit it would have a capacity of only 43.5 amperes at 230 volts, whereas a 10-kw. 230 volt motor should have a capacity of 50 amperes, (assuming an efficiency of 87 per cent). The 10-kw. generator could, therefore, be only rated at 8.7 kw. as a motor. Although the reasons for this are perfectly clear to the engineer, it would be confusing to the non-technical public, inasmuch as both generator and motor are given the same rating. This condition represents an apparent inconsistency in the new method.

Until the new system of temperature ratings has thoroughly adjusted itself, we should continue to use the horse power as the unit of power.

J. W. Welsh (communicated after adjournment): From the standpoint of the operating engineer, any method of rating apparatus in which the full load continuous output can be secured only at the expense of attaining the maximum permissible temperature rise, hardly appears to be a safe basis of operation.

In eliminating all overload ratings for continuously rated apparatus it is believed that too radical a step is being taken. There are certain usages where this is less objectionable than others. For example, in a large generating station where the load is comparatively steady it is possible to operate a machine

continuously at its maximum rating. At the other end of the system and at intermediate points where the diversity factor is lower, the fluctuating nature of the load as well as the prominence of the peaks make an overload capacity in the apparatus highly desirable.

The maximum capacity required is determined by the peak. It is believed that for the same materials and ultimate temperature in a given piece of apparatus, a greater ultimate rating on the basis of a short peak can be given, than would be permitted for the maximum rating on a continuous full load basis. In other words a maximum rated machine if operated at less than rating, should pull an overload above its maximum continuous rating for a short time with the same ultimate temperature. Moreover, as brought out in the paper of Mr. Steinmetz and Mr. Lamme, if the same ultimate temperature is attained both with peaks of short duration and for continuous operation, the life of the apparatus is increased in the former case.

A further objection to rating up apparatus to its maximum continuous output, is the bad effect on certain operating characteristics, such as the starting and running torque of motors, the commutating limit in d-c. apparatus, etc. The values proposed for these are considerably less than those which were guaranteed in specifications under the present rules. From this it appears that the margin of capacity has been cut down here as in the case of temperature rise. In other words, it is difficult to secure good operating characteristics at what amounts to overloads on the old basis.

The recommendation is therefore made, that the full load continuous rating be fixed on such a basis as will still permit of overload ratings for a one hour or two hour peak in addition to the momentary overload. The ultimate permissible temperature should then be adjusted to meet these ratings.

Referring now to the report on *Method of Rating Electrical Apparatus*, in specifying the ultimate temperature as the basis of rating apparatus rather than the temperature rise, it is believed the exactness of the specified rating is sacrificed. If the ultimate temperature is fixed, it is also necessary to fix the temperature of the cooling medium. If for example the ultimate temperature is fixed at 90 deg. cent. and the cooling air at 25 deg. cent. the temperature rise is 65 deg. cent. which will certainly permit of a greater rating than if the cooling air is taken at 40 deg. cent., which corresponds to a 50 deg. rise.

While it is possible to measure the ultimate temperature of apparatus with a considerable exactness, it is believed that the determination of the true temperature of the cooling medium will be found more difficult.

The temperature of the cooling medium should be taken as that of the outside air when this is brought in through ducts for cooling purposes. To take the room temperature immediately surrounding the machine appears to be charging off the temp-

erature rise twice, since the room temperature is the result of the fact that the heat given off from the apparatus has raised the temperature of the cooling medium. The room temperature in this case has no more bearing on the situation than has the hot temperature of the cooling water leaving a water cooled transformer.

In case of apparatus operated without forced ventilation it is obviously unfair to take the air temperature in the immediate vicinity of the apparatus, since as in the above case this represents a rise in temperature of the cooling medium due to the heat generated in the apparatus istelf. If there is no other heat-emiting object in the room in which the apparatus is located, and the natural ventilation through the doors and windows is such that with the apparatus running at rated load, a constant temperature gradient is reached within the room, then the case becomes similar to that of forced ventilation, the only difference being the rate at which cold air is supplied from the outside. The temperature within the room will of course vary at different points, being hottest near the apparatus and coolest at the doors or windows. In this case also, it is believed that the temperature of the cooling medium should be that of the incoming air as measured within the room, near the doors and windows.

Edmund C. Stone (communicated after adjournment): Operating men cannot take too much to heart the fact, so clearly brought out in the paper, that each overload producing an excessive temperature materially weakens the insulation of the machine and shortens its life by a perfectly definite amount.

With the gradient of 10 to 15 deg. of the hottest parts above the rise obtained by conventional methods is sufficient for machines of the best design, many manufacturers are offering apparatus having the same temperature guarantees but much less ventilation. A purchaser, therefore, is not always protected by a measurement of rise by the usual methods—he must either actually measure the temperature of the hottest parts of the machine or be able to judge fairly accurately the value of the ventilation actually provided.

Machines in the past have been so liberally designed that they have actually been good for a continuous load much above their rating. It is now possible to predetermine the performance of a given design far closer than in the past. Hence machines now put out come very close to the guaranteed rise. If, under these conditions, the full load guaranteed rise is made the maximum safe rise of the machine, it is obvious that the customer will not get as much for his money as heretofore.

Regarding the question of a single rating, it seems to me that in addition to the rating the manufacturer should furnish a "time-overload" curve, showing the length of time that a machine can carry various overloads.

This is of supreme importance because of the sharp peaks that are a characteristic of many types of commercial load. For in-

stance, one substation has a one hour peak 35 per cent in excess of its normal load, during three months of the year only. It would be needlessly extravagant to buy for this station apparatus having a continuous rating equal to this peak.

For such reasons as this it is impossible for any operating man to use his apparatus economically unless he has a good knowledge of its heating characteristics.

William F. Dawson (communicated after adjournment): Considerable timidity has been expressed over the recommendation of Dr. Steinmetz and Mr. Lamme to establish a maximum measurable temperature of insulation made from organic materials, as 90 deg. cent. The testimony of Messrs. Steinmetz and Lamme, frequently repeated, that they have found this a conservative limit should, in view of their great experience, satisfy most critics.

Their recommendation is to a large extent supported by most exhaustive and interesting tests made at the National Physical Laboratory, Teddington, London, for the Engineering Standards Committee (English) in a paper entitled " Report on Temperature Experiments " and read by Mr. Raynor and Dr. Glazebrook before the Institution of Electrical Engineers, March, 1905.

Attention is also directed to a paper on " Temperature Curves and Rating of Electrical Machinery " read at the same meeting by Mr. Rudolph Goldschmidt, both papers containing illuminating information on the subjects discussed.

The writer agrees with the sub-committee report in regard to heating of commutators, but would point out that the commutator connections of many machines, especially those of generators direct connected to slow speed engines and even on many motor generator sets and synchronous converters are of such length that the nature of the armature insulation can be happily ignored in placing limits on commutator heating.

When carbon brushes were first introduced on machines which had previously been supplied with copper brushes commutator radiating surface was restricted and the temperature rise of 55 deg. cent. on the commutator was usually guaranteed and accepted, and proved satisfactory.

The recommendation of the sub-committee in regard to bearings is endorsed, and it is particularly pointed out that bearings, and bearing oil, can be operated at much higher temperatures than generally supposed. High temperatures are practically essential to the operation of high speed turbine bearings, as the friction decreases with increase of temperature. With properly designed bearings and suitable oil and oiling system 100 deg. cent. may be considered a perfectly safe temperature limit.

The fields of maximum rated turbo-alternators are so designed that if 50 per cent overload at standard fractional power factor is applied the voltage must fall below normal. This is desirable, as otherwise there will be a tendency to damage the machine from overloads. The writer suggests that the " reason to be "

of the 50 per cent overload stipulation and its period are debatable. It would seem desirable to allow this overload to permit the starting of additional machines, in case of sudden and unexpected demand for extra current such as occurs in certain localities from a sudden thunder storm or fog. He questions if 60 seconds is quite sufficient; 2½ or 3 minutes would seem more appropriate.

The absence of overload guarantees except as suggested above is exceedingly appropriate with modern high speed machines, particularly of moderate voltage, as the rapid movement of air notably reduces the thermal "surface drop" and makes possible the comparatively high loading of the copper conductors. Conditions, however, are different on comparatively slow speed machines, such as for direct connection to steam engines, gas engines and low speed waterwheels. Here the surface drop is not reduced to the same extent and consequently for continuous operation the conductors cannot be given the same loading and, therefore, have a considerable reserve of thermal capacity so that is would be appropriate to discuss short time overloads, say of half an hour, or an hour.

The writer endorses the Committee's recommendation to rate alternating current generators in kilovolt-amperes rather than in kilowatts. He would, however, point out that many turbo-alternators have their capacity limited by the field, and that as even at 80 per cent power factor the field current for kilovolt-ampere rating has not reached maximum value, the power factor should always be specified. The field current at power factors varying from 100 to 0, (kv-a. remaining constant) for three typical turbo-alternators, is indicated by the following table:

	Power Factor	Field Amperes
Example I:	100 per cent	103.2
	90 " "	122.9
	80 " "	129.2
	60 " "	136.8
	0 " "	143.5
Example II:	100 " "	85
	90 " "	101.3
	80 " "	106.9
	60 " "	113.0
	0 " "	118.5
Example III:	100 " "	61.3
	90 " "	73.5
	80 " "	77.5
	60 " "	82.0
	0 " "	86.5

Synchronous converters are susceptible to additional heating from wattless currents, and when intended for use in part as synchronous condensers the requirements should be carefully specified.

Philip Torchio (communicated after adjournment): In conformity with the understanding at the meeting of February 26th

that certain parties should submit in writing their further comments on the proposed revision of rules and rating; I beg to state the following:

There seems not to have been any substantial difference of opinion upon the question of substituting a single rating in place of a normal load rating with overloads, provided the rating were sufficiently conservative. From the discussion at the meeting it developed that there is a substantial discrepancy in the recommendations of the two sub-committees.

Messrs. Steinmetz and Lamme's committee recommended "a maximum rise of temperature of 50 deg. cent. by *conventional methods* of measurement or 60 deg. cent. at the *hot spots*," the difference of 10 deg. cent. being due to temperature grading in insulation. On the other hand, the committee on revision of rating recommended "a maximum rise of 50 deg. cent. at the *hot spots*," which, in accordance with the previous report, would be equivalent to 40 deg. cent. rise by *conventional methods.*

As everybody seems to agree that this difference of about 10 deg. cent. between conventional measurements and actual temperature at *hot spots* (temperature grading) is about representative of actual conditions, and as it appeared from the discussion that it is almost impossible, except for a very expert engineer, to locate the *hot spots*, therefore, I do recommend that the *conventional methods* of measurement be retained and that 40 deg. cent. be the maximum rise of temperature allowable by *conventional methods* and 50 deg. cent. at the *hot spots.*

In other words, the standard rating should be based on *conventional methods* of measurement of temperature as the ordinary customer would not be in a position to check the rating of his apparatus if the *elusive hot spots* are to be the basis of rating.

In conclusion I therefore recommend that, to safeguard the interests of the general consumer of electrical power, the Institute's standard rating be based on 40 deg. cent. rise above room temperature, the measurements to be made by any of the present *conventional methods*, also that the machine is to operate at any room temperature up to 50 deg. cent. without making any temperature correction in determining the rise and that 50 + 40 = 90 deg. cent. be the maximum total temperature at which machine be operated.

DISCUSSION ON "THE MYRIAWATT" (STOTT AND O'NEILL), BOSTON, MASS., JUNE 26, 1912, AND NEW YORK, FEBRUARY 27, 1913. (SEE PROCEEDINGS FOR JULY, 1912).

(Subject to final revision for the Transactions.)

H. G. Stott: A great deal of criticism has been made on this paper, which was presented at the convention held in Boston last June. The greater part of this criticism, I think, is entirely due to a misconception. The misconception is that we are endeavoring to introduce a new unit. A little careful consideration of the paper would show that that conception is entirely wrong. All that was attempted to be done was to get in the thin end of the wedge, as it were, of the metric system into our measurements of mechanical power. We all know how we suffer at the present time from the numerous illogical and irrational units which are used in calculations on thermodynamics and mechanical units of power. For example, we have the boiler h.p., which was originally meant to mean that the boiler could evaporate 30 lb. of water from a temperature of 100 deg. to steam at 70 lb. Now latterly it has been modified to mean the amount of heat required to evaporate 34.5 lb. of water at a temperature of 212 deg. fahr. This is purely arbitrary, and has no scientific or rational basis.

There is still another boiler h.p., and that is one which simply means it is equal to 10 sq. ft. of heating surface in the boiler. The h.p. is sometimes used in the sense of being shaft h.p., sometimes brake h.p., and also for the indicated h.p. of an engine.

There are at least half a dozen different values attached to this term of horse power, and it seems to me that it is a happy coincidence that 10 kw. are just about equal to one boiler h.p., that is, within two per cent of it. The line of least resistance is always the best one to adopt in trying to introduce the metric system to those who have been accustomed to the abominable English system of units, and that is the basis of our attempt.

There has been a great deal of criticism directed against the unit which we propose. The first one is, why not use the kw. at once? The trouble with that is that you immediately have to introduce the factor of 10; say that 10 kw. are equal to 1 boiler h.p., which is approximately true. Then there is the difficulty in nomenclature, in referring to the fact that you require 10 kw. to deliver one kw. at the switchboard. Now, it seemed to us to be a little simpler to use the prefix "myria", meaning 10,000. The precedent for that is that in the metric tables we have the millimeter, the centimeter, the decimeter, the meter, the dekameter, the hectometer, the kilometer, and the myriameter.

Now, the same thing is true with the gram. We find there the myriagram also. So that there is absolutely nothing new about it, and we simply apply the well-known prefix of "myria" to the watt. The kilowatt is not the unit, the watt is the unit. We have not introduced a new unit, but have used a prefix well-known in Continental practise, the prefix "myria" to indicate

10,000 times. Now, the whole object of this little paper, the idea of introducing the myriawatt, as I have said before, was to begin gradually, from the easiest point of attack, the introduction of the metric system into mechanical and thermodynamic calculations. The introduction of such a unit, it seems to me, will help a great deal, because naturally the next step, for example, in calculations on steam, will be the use of the centigrade thermometer scale. We are all familiar with that in electrical work. With the fahrenheit scale in calculations on thermodynamics, you are continually troubled with the plus or minus 32 deg. and it is a constant source of error.

With the centigrade scale that is eliminated, so that the next step I hope to see introduced is the abandonment of the fahrenheit scale and the introduction of the centigrade scale for all thermodynamic work involving calculations. These things are all time-savers, just as the entire metric system is a time-saver over the old English system of units.

There is another reason for the introduction of this term. It has heretofore been the custom to specify the performance of a steam unit in pounds of steam. That was a perfectly legitimate and a perfectly safe way of expressing it, as long as there was no superheat, and as long as you worked to constant vacuum, for the vacuum varied but slightly from twenty-six inches as the standard. But nowadays, when we are going to 28.5, 28¾, 29 and 29¼ inches actual vacuum in guarantees, when referred to 30 in. barometer, and when the superheat may vary from 100 deg. to 200 deg., the pounds of steam per kw-hour mean nothing; you must get down to thermal units. The transformation from the thermal basis of the B.t.u., or the calories, is very simple, and is given in that little paper, so that we would naturally expect that, in expressing it in myriawatts, the conversion into the thermal units is implied, because that is a very simple matter by the use of a steam table.

The question of getting steam tables which are required in the metric system, is also now being taken up, and the authors of the tables best known today, have agreed that if the metric system of units in thermodynamics is adopted they will have their tables translated into the metric system.

Electrical engineering and mechanical engineering are now so closely allied and actually connected by the steam turbine that it is impossible to determine the efficiency of one without the other. There is no way I know of, of separating the losses in the turbine and in the generator. That comes in as an appropriate part of this matter, so that the electrical engineer is as much interested in this subject, in my opinion, as the mechanical engineer, and therefore I think if we do all we can to assist in the adoption of the metric system in all tests and guarantees, the rest of it will come very quickly. It is a very simple matter, all we have to do is to introduce the centigrade thermometer, and then the only quantity we have to translate will be pounds of water into kilograms. Then we will have our

tests, reports and guarantees on precisely the same basis as they have in Europe; in other words, we will have our results in international units. At the present time, if we take up the results of tests on the steam turbine units which are practically the only sources of power in large stations now, we find that it is impossible, at first sight, to compare the European results with our own results. We have to sit down and go over a series of laborious calculations.

Now, if we become accustomed to the calorie, kilogram and the centigrade scale, which all electrical and chemical engineers are using, it would be a very simple thing to work out all our tests and all our guarantees in the metric system of units.

C. P. Steinmetz: If you want to realize the importance of getting to an intelligible system of nomenclature, you only need to consider a sentence like this: To operate ten 300-ton trains per day, at 40 miles per hour, with an acceleration of 0.5 mile per hour per second, two 2000-kw. turbo-alternators are installed. The periodicity of these generators is 25 cycles per second; they are designed for a temperature rise of 40 deg. cent. Their speed is 1500 rev. per min. and they are cooled by the circulation through each of them of 10,000 cubic feet of air per minute. This circulation is maintained by a pressure of 1.5 inches. Their consumption is 11 lb. of steam per kw-hr. at 175 lb. boiler pressure and 75 deg. fahr. superheat, and a 28-in. vacuum. Steam is supplied by six 300-h.p. boilers, consuming 2 lb. of coal per boiler h.p. The coal has a thermal value of 14,000 B.t.u. per pound. 1000 gallons of condensing water per minute are required at full load.

Now, pick out the number of heterogeneous, incompatible and erratic units in that brief statement, and then imagine how any sensible engineer can really maintain that such a system of units does not constitute a terrible and foolish handicap to progress in engineering.

Comfort A. Adams: It seems to me a crime, that men who call themselves engineers, who talk much about efficiency in the machines they develop, will continue to encourage the perfectly inhuman and wasteful system of units so aptly described by Dr. Steinmetz, when its use involves a loss in efficiency on the part of every one of us, of every man who has anything to do with engineering, which is almost incredible. I believe it is a conservative statement that the average engineer wastes a working year of his life by the use of our messy system of units. Frequently a student of limited capacity will fail to grasp the real physical significance of a problem, because of the confusion of units.

The myriawatt is only a step, but in the right direction. We are fortunate in having such a good representative as Mr. Stott in the American Society of Mechanical Engineers. He should certainly have the vigorous support of every electrical engineer.

Leo Schuler: I have learned with great pleasure that the European engineers are working at about 2.5 per

cent greater efficiency than you do, and I do not think that I need say anything additional to what has been said in favor of the introduction of the metric system in engineering work in the United States. Nevertheless, I would not propose that you begin this reformation by the introduction of another new unit, the myriawatt, as proposed. The kilowatt is such a well-known unit already, even here in America, that I think confusion would be increased by another word, the myriawatt; I must also say that Mr. Stott is mistaken if he thinks that the prefix " myria " is very well known in Europe. As a matter of fact, it is not. Nobody uses it as a prefix, neither for myriameter or anything else. I think it would be better to say 10 kilowatts instead of one myriawatt.

In regard to the introduction of the kilowatt as a mechanical unit, that is making good headway and the Society which I represent here at this meeting, the Verband Deutscher Elektrotechniker, has already decided to rate electric motors in kilowatts, beginning January 1, 1914. It was arranged to give the manufacturers about two years' time for changing their nameplates and types. They could not rate a one-h.p. motor at 0.746 kilowatts but they must have it in round figures. There has been practically no difficulty in introducing the kilowatt by the Verein Deutscher Ingenieure, and the proposed new expression, the "neupferd", or in English, the " new horse," has been proposed, not by the mechanical engineers but by the electrical engineers, to facilitate its introduction by the mechanical engineers; the mechanical engineers, however, say that they do not want it, that they can understand " kilowatt " well enough.

H. M. Hobart: It has been my experience that here in America the 2000-lb. ton is the chief stumbling block to the introduction of the metric system. The other stumbling blocks to which Mr. Stott and Dr. Steinmetz have alluded are serious, but the 2000-lb. ton is the chief difficulty. There is not much good to be accomplished in getting people to change pounds into kilograms, if you are going to have the irrational relation between the kilogram and the ton, yet you will rarely find an American engineer who will countenance any notion that there can be anything better than the American ton. In this matter of the 2000-lb. ton, America stands alone. The 2000-lb. ton is never used by engineers in the British Empire. If in England it is said that the weight of anything is 100 tons it is taken as a matter of course to mean 100 tons of 2240 pounds. The English ton is 2240 pounds. The metric ton is equal to 2204 pounds, but the difference of only about one per cent is so small that it would not affect one engineering calculation in a thousand. If you can accustom people to speak in tons, you have a common bond between the metric system and the English system, and the way is smoothed for introducing the kilogram, which for all practical purposes is the one-thousandth part of the English ton. This is the connecting link which is not available in America, and in my opinion

it is to a considerable extent for this reason that the metric system is used far more extensively in England than in America. America is away behind in the introduction of the metric system. Some six or eight years ago I worked out a set of steam tables, at a tremendous expenditure of labor, in which I gave the energy in kw-hr. per ton of steam for all temperatures and pressures, and with vertical columns for various degrees of superheat —no superheat, 50 deg. superheat, 100 deg. superheat, and so on, and I published these tables in a book entitled "Heavy Electrical Engineering." I do not believe these are yet used by anyone except myself. I am pleased to hear the proposal by Mr. Stott that tables of this kind should be employed. They are already available in the book to which I have alluded.

Charles P. Steinmetz: I entirely agree with Professor Adams that it is a crime for mechanical engineers to hold on to a mis-system of units, but I know of a greater crime still, and that is that men who do not have to deal with factory foremen or boiler testers or other people of limited horizons of intelligence, incapable of understanding anything new,—that men who are working, not for today, but for future generations, that is, very many educators throughout our educational institutions, our colleges and universities, in the electrical engineering departments, teach the English system with its inches, pounds, and gallons, its British thermal units and its fahrenheit degrees, first, because they desire to pose as practical men and secondly because they are too inveterately lazy to do anything but drift.

Now, there is where we can do more good than anywhere else, by *really giving the instruction* in the metric system. It would materially increase the efficiency of the work of these sound engineers to impart the metric system to them. You cannot transfer quickly from anything to anything else, say from an electrical phenomenon to a thermal phenomenon, without running the chance of being hopelessly mixed up, by the use of the English system, and you need the metric system to assist you.

I believe what ought to be done is that universities and colleges should teach, not simply and purely the metric system, but they should very thoroughly teach the method of reduction from the English to the metric, and from the metric to the English system, and educate the new generation to do all calculating work in the metric system, and to transform given data, which are in the English system, into the metric system, by calculations in the metric system, and retransform the results back from the metric system into the English system. This gives a much higher degree of reliability to the calculation, because it eliminates the enormous possibility of making a mistake in the irregular, irrational reduction factors, in using thermal units, and foot-pounds and kilowatts, and boiler horse power, and any one of the twenty-five different units for the same quantity.

I was very badly mixed up in my last attempt at using the English system, and I found it necessary to transform all the data procured from the English system, into the metric system,

do all the calculating metrically, and transform the results back. It is much more efficient to do this.

After all, what we want to do in educating young engineers is to educate them to do the work efficiently. The most efficient way, naturally, is by the exclusive use of the metric system, but as long as the practical men are always lagging one or two generations behind the world, and they are still using the English system, the next efficient way would be to do all the work in the metric system and transform from the English to the metric, and from the metric back to the English, in using the terms and giving the results.

B. G. Lamme: I am fully in accord with any move to rate motors in kilowatts, instead of horse power. There is one fortunate thing, with our present mixed system, which will help us in making this change. We have been rating apparatus largely in halves, quarters and eighths, instead of in decimals of horse power, and the relation between the kilowatt and horse power is practically three-fourths, so that in a great many cases, in changing from horse power rating to the kilowatt, we do not obtain any particularly odd ratings. For instance, 50 h.p. would be changed to 37.5 kw., which is at present in common use in generating apparatus. One h.p. would mean 0.75 kw. We would therefore be able to change to the kilowatt rating with very little confusion.

James Burke: I think there is considerable advantage, sometimes, in having both systems—it sometimes gives us a chance to think what we are going to say in answer to a question, while we are apparently taking time to convert from one system to the other. There is also a certain romantic influence in maintaining some of the old units. I come from a part of the country where we still talk of "two bits" instead of twenty-five cents.

I would ask Mr. Schuler if it is not true that in Germany they still use the 60 seconds for a minute and 60 minutes for an hour? In this country the decimal hour has come largely into use in manufacturing and time records in manufacture are kept in decimal parts of the hour. I would also like to ask Mr. Schuler if it is not true that in Germany the English system of threads on bolts, nuts and screws is still the commercial system, rather than the metric system.

Leo Schuler: Of course, Mr. Burke knows that it is so, and he need not ask.

I would say, in reply to what Mr. Lamme said, that the time lost is not only in making the transformation, but you have to transform from one kind of unit to another kind of unit in your calculations. For instance, when you wish to calculate the energy stored in a moving mass, if the mass is given in kilograms and the speed in meters per second, then the fraction $\frac{m\,v^2}{2}$ equals watt-seconds.

A. E. Kennelly: How far are they using the metric system in screw threads in Germany?

Leo Schuler: Metric screws are used for small apparatus only. For machinery screws, generally the Whitworth system is used.

L. W. Chubb: In expressing any physical quantity it is better to follow the most common custom. In speaking of power it is customary to speak of watts when below 1000 and kilowatts above this figure. A 20-megawatt generator was mentioned yesterday, but such an expression of rating is uncommon.

The most familiar and desirable prefixes are limited to every third digit and every third decimal place. "Kilo," "mega", "milli" and "micro" are common and desirable. Deka, hecto, myria, deci, centi, are uncommon, except in the case of centimeter, which in reality is the working unit, and one of the three fundamental metric units.

What is wanted is standardization and not deception. The myriawatt seems to have no advantage except to deceive the uninitiated regarding the efficiency of the mechanical end.

Charles P. Steinmetz: I do not agree as to the difficulty of introducing the myriawatt. I think it would be difficult to introduce the kilowatt in this connection, for two reasons; first, it means a rise of 10 points, that is, where the practical man would speak of a 100-h.p. boiler, it would be necessary to speak of a 1000-kw. boiler, and that is beyond the mental capacity of the users of the English system. We must consider that we are not all engineers, but that the majority of the people who are using the English system are working men, and factory foremen, etc., and that must be considered, and it would be a hardship to have everything increased in numerical value by ten-fold. Under the plan which we are now considering, in order to supply steam to a 100-kw. generator, a 1000-kw. boiler would be required, and that would be a difficult designation to bring about amongst the less educated people. Moreover the educated mechanical engineers would also rather resent the adoption of a nomenclature which would disclose the low efficiency of mechanical and thermodynamic transformations.

After all, we have to realize that the persistent adherence to the English system by mechanical engineers is not altogether conservative, but there is also a rather mixed feeling, not to say consciousness, the feeling that if they go to a system of units based upon the metric system it does not look well. It does not look bad to say you use so many pounds of coal per B.t.u., and that there are so many B.t.u's. in a certain number of kilowatt-hours, but it does look bad to say that you use 15 joules of coal to produce 10 joules of steam energy, and that 10 joules of steam energy are required to supply 1 joule of electrical energy. The metric system shows up the efficiency of transformation.

We have nothing to be ashamed of as electrical engineers, but the mechanical engineers are faced by the inherently low efficiency of mechanical and thermodynamic transformations, and they do not care to flaunt these low efficiencies too much before the public.

REPORT OF THE LIBRARY COMMITTEE

For Year Ending April 30, 1913

Board of Directors, American Institute of Electrical Engineers.

GENTLEMEN:—In accordance with Section 24 of the By-Laws of the Institute, we beg leave to submit herewith our annual report for the year ending April 30, 1913, showing the state of the library and including the names of all donors to it.

During the year the erection of two ornamental metal book-cases, one on each side of the main entrance to the library on the 13th floor, has been completed. These are intended to serve for storage and display of a large portion of the Latimer-Clark collection of books which was donated to the Institute by Dr. Schuyler Skaats Wheeler.

As a result of the combined efforts of the Library Committees of the three founder societies, and of the Joint Conference Committee, an organization for the administration of the library by a library board subject to the direction of the Board of Trustees of the United Engineering Society, has been effected, with the approval of the Boards of Directors of these founder societies. The character of the organization is set forth in the following extract from the By-Laws of the United Engineering Society, which went into effect in November, 1912.

Library and Educational Work

74. The Board of Trustees shall maintain and conduct a Free Public Engineering Library, subject to such regulations as it may from time to time determine.

75. The library shall be conducted by a Library Board, subject to the direction of the Board of Trustees.

76. The Library Board shall consist of sixteen members, composed as follows:

Four members designated by each of the three Founder Societies.
The Secretary of each of the three Founder Societies.
The Librarian, who shall also be the Secretary of the Board.

One member shall be designated by each Founder Society each year to serve four years.

Any vacancy occurring among the appointed members shall be filled by the corresponding Founder Society for the unexpired term.

77. Regular meetings of the Library Board shall be held on the first Thursday of February, May, September and December of each year. Special meetings may be called at the option of the Chairman, on not less than seven days' notice, and must be called by the Chairman on the written request of seven or more members. A quorum shall consist of not less than seven members, of whom at least four shall be appointed members, including at least one such member from each of the Founder Societies.

78. At its first regular meeting in each calendar year the Library Board shall elect one of its members to be Chairman for a period of one year or until his successor is elected. At the same meeting the Library Board shall elect from its own members an Executive Committee to consist of an equal number of members from each of the Founder Societies, to serve for one year. The Chairman of the Library Board shall be ex-officio a member and Chairman of the Executive Committee. The Librarian shall be ex-officio Secretary of the Executive Committee, but shall have no vote.

79. If less than a quorum be present at a meeting of the Library Board the members present may adjourn the meeting to a day fixed.

80. The Library Board shall have authority

To originate, revise and approve rules for the administration of the library.

To prepare and forward to the Board of Trustees, requisitions for furniture and other supplies.

To appoint and fix salaries of employees in the library, subject to the approval of the Board of Trustees.

To revise and approve lists of publications authorized by the Founder Societies for purchase, with a view of avoiding unnecessary duplication.

To direct the purchase on account of the UNITED ENGINEERING SOCIETY of publications not on file in the library, under such regulations and within such limits as the Board of Trustees may prescribe.

To receive and administer bequests and gifts to the LIBRARY OF THE UNITED ENGINEERING SOCIETY.

81. At the end of each calendar year the Library Board shall present, to the Board of Trustees and to the Founder Societies, a full report of its acts during the past year, including a financial statement of its receipts and disbursements and its recommendations for the coming year as to policy and finance. This report shall state the recommendation of the Library Board as to the sum of money which each Founder Society should expend during the coming year for the purchase of books for the library of that society; and as to the sum which the United Engineering Society should expend for the purchase of books or periodicals for the Library of the United Engineering Society; and as to the sum each society should contribute toward the cost of administration.

82. A regular meeting of the Executive Committee shall be held on the first Wednesday of each month except July and August. Special meetings may be called by the Chairman. A majority of the members shall constitute a quorum, but a less number than a quorum may adjourn the meeting to a day fixed. The Secretary of any of the Founder Societies may be present at any meeting and shall have the same right as members to be heard, but shall have no vote. Notice of each called and adjourned meeting shall be sent to each such Secretary.

83. The Executive Committee shall be the representative of the Library Board and shall execute the instructions of the Library Board, and whenever necessary shall take any action for which the Library Board has authority, reporting such action for approval to the Library Board at the next following meeting of said Board.

84. The Librarian shall be appointed by the Board of Trustees from a list of names submitted by the Library Board.

85. The Librarian shall be the Executive of the Library Board and of its Executive Committee, and, subject to the direction of said Board and Committee, shall have charge of the library.

86. The Librarian shall be a member and the Secretary of the Library Board, and the Secretary, but not a member, of the Executive Committee.

87. At each meeting of the Library Board the Librarian shall submit a written report containing his recommendations for the purchase of books and supplies, and for any changes in service or in the work of the library.

88. The Board of Trustees shall also co-operate with the Founder or Associate Societies in giving public lectures on engineering and scientific subjects and in arranging for the conduct of educational and research work as from time to time may be deemed advisable.

The Library Board was organized on February 6, 1913, with Dr. Leonard Waldo as Chairman.

Statistical information concerning the library and its use during the year, including a list of donors, is given in the following tables:

DONORS

May 1, 1912—April 30, 1913

ADAMS, E. D.	8
AMERICAN ELECTRIC RAILWAY ASSOCIATION	4
AMERICAN ELECTROCHEMICAL SOCIETY	1
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS	3

AMERICAN JOURNAL OF SCIENCE	2
AMERICAN RAILWAY ASSOCIATION	1
AMERICAN SCHOOL OF CORRESPONDENCE	4
AMERICAN TELEPHONE & TELEGRAPH COMPANY	1
ARNOLD, B. J	12
MR. BISSING	1
BENEDICT, V. L	1
P. BLAKISTON'S SON & COMPANY	1
BOSTON TRANSIT COMPANY	1
BOSTON WIRE DEPARTMENT	1
BUCHANAN, J. Y	2
BYLLESBY, H. M	1
CALDWELL, EDWARD	1
CARNEGIE INSTITUTION OF WASHINGTON	2
CENTRAL STATION PUBLISHING COMPANY	1
CHANDLER, C. de F	2
CONGRESO CIENTIFICO	1
CUSHING, H. C	1
DEPARTMENT OF AGRICULTURE	1
DEPARTMENT OF LABOR	2
DEPARTMENT OF TERRESTRIAL MAGNETISM	2
DUNOD & PINAT, PARIS	1
EICKEL, E	1
ELECTRICAL RAILWAY JOURNAL	1
ENGINEERING NEWS COMPANY	7
FORTSCHRITTE DER PHYSIK	1
FOWLE, F. F	5
GATI, M. B	1
GAUTHIER, VILLARS	3
GEROSA, E	1
HANSEN, L	1
HEIMAN S. & SOHN	1
HERING	1
HERMAN ET FILS, A	2
HOLMGREN, T	2
INDIA RUBBER JOURNAL COMPANY	1
INSTITUTION OF ENGINEERS AND SHIPBUILDERS, SCOTLAND	1
INTERNATIONAL ELECTRIC PROTECTION COMPANY	1
INTERNATIONAL ELECTRICAL CONGRESS, ST. LOUIS	1
IOWA ELECTRICAL ASSOCIATION	1
IOWA ENGINEERING SOCIETY	1
ISOLATED PLANT PUBLISHING COMPANY	1
KANSAS, GAS WATER AND STREET RAILWAY ASSOCIATION	1
KENNELLY, A. E	6
KAHN, H. R	1
LAUFFER, C. A	1
LIBRARY OF CONGRESS	1
LIPPINCOTT COMPANY	2
LOUBAT & CIE	1
MACMILLAN COMPANY	2

MAILLOUX, C. O.	1
MARTIN, T. C.	10
MARYLAND PUBLIC SERVICE COMMISSION	1
MASSACHUSETTS GAS & ELECTRIC LIGHT ASSOCIATION	1
MASSACHUSETTS INSTITUTE TECHNOLOGY	1
MAVER, WILLIAM, JR	6
McALLISTER, A. S.	1
McGRAW-HILL BOOK COMPANY	2
McPHERSON, L. G.	1
MERSHON, RALPH D.	1
MOIS SCIENTIFIQUE ET INDUSTRIAL	1
MOURLON, CHAS	1
MUNICIPAL ENGINEERING COMPANY	1
MURALT & COMPANY	1
NACHOD SIGNAL COMPANY	1
NATIONAL ELECTRIC LIGHT ASSOCIATION	3
NATIONAL BOARD OF FIRE UNDERWRITERS	1
NATIONAL CIVIC FEDERATION	1
NATIONAL ELECTRIC LIGHT COMPANY	1
NATIONAL FIRE PROTECTION ASSOCIATION	4
NATIONAL WATERWAYS COMMISSION	1
NEW ENGLAND WATER WORKS ASSOCIATION	2
NEW JERSEY BOARD RAILROAD COMMISSION	2
NEW ORLEANS SEWERAGE AND WATER BOARD	1
NEW YORK BOARD OF FIRE UNDERWRITERS	1
NEW YORK BOARD OF WATER SUPPLY	1
NEW YORK ELECTRICAL SOCIETY	1
NEW YORK STATE DEPARTMENT OF LABOR	3
NEW YORK STATE PUBLIC SERVICE COMMISSION	3
NOEGGERATH, J. E.	1
NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIP-BUILDERS	1
NORTH EAST COAST POWER SYSTEM COMPANY	1
OSTERREICHISCHER BETON VEREIN	1
OURO PRETO SCHOOL OF MINES	9
PAINT MANUFACTURERS ASSOCIATION OF THE U. S.	1
PHILADELPHIA DEPT. OF PUBLIC WORKS	1
PIERCE, A. L.	2
PLATTHER, WM	1
POLYTECHNIC INSTITUTE OF BROOKLYN	1
PRADO, H. C.	1
RAILWAY AGE GAZETTE	1
RAILWAY SIGNAL ASSOCIATION	1
RENSSELAER POLYTECHNIC INSTITUTE	1
SCHOEN, A. M.	1
SCOTT, FORESMAN & COMPANY	1
SEVER, G. F.	1
SIEMEN & HALSKE	1
SOCIETY OF CHEMICAL INDUSTRY	2
SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION	1

SOUTH WALES INSTITUTE OF ENGINEERS	1
SOUTHWESTERN ELECTRICAL & GAS ASSOCIATION	4
SPERRY, E. A	1
TELEPHONE PIONEERS OF AMERICA	1
THOMPSON, SLASON	1
TRANSVAAL INSTITUTION OF MECHANICAL ENGINEERS	1
TREASURY CONSTRUCTION SOCIETY	1
U. S. BUREAU OF STANDARDS	2
U. S. NATIONAL MUSEUM	1
U. S. WAR DEPARTMENT	2
UNIVERSITY OF LONDON PRESS	1
UNIVERSITY OF MINNESOTA	1
UNIVERSITY OF PITTSBURGH	1
VAN NOSTRAND, D. COMPANY	6
WARE, H. E	1
WEAVER, W. D	2
WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY	1
WHITEHEAD, J. B	2
WILEY, J. & SONS	1
ZEHNDER L	4
ZEITSCHRIFT FUR BELEUCHTUNGSWESEN	1
DONOR UNKNOWN	4
OLD MATERIAL	26
	258

Exchanges	172	
Purchases and old material accessioned	399	
		571
Total accessions		829

The following tabulation gives the state of the accounts from which the Library Committee is entitled to draw:

DONATIONS (GENERAL LIBRARY FUND)

DR.		CR.	
Balance May 1, 1912	$271.15	Unexpended	$277.95
Interest	6.80		
	$277.95		$277.95

MAILLOUX ENDOWMENT FUND ($1,000)

(Proceeds for the maintenance of certain sets of periodical publications)

Balance May 1, 1912	$78.55	Expended	$46.00
Interest	45.00	Unexpended	77.55
	$123.55		$123.55

International Electrical Congress of St. Louis, 1904, Fund

(Proceeds available for the purchase of non-American international electrical literature)

Invested in New York City 4½% Bonds.	$2268.00
Additions to the Fund	76.85
Total Fund	$2344.85

Balance on hand May 1, 1912	$309.12	Expended	$3.88
Interest	90.00	Unexpended	$395.24
	$399.12		$399.12

Weaver Donation

(Available for the purchase of early electrical literature)

Balance May 1, 1912	$6.69	Unexpended	$6.69

Institute Appropriation Account

Appropriation for the year	$4500.00	Salary (one-third) of librarian, assistants, cataloguer and desk attendant, May 1, 1912 to May 1, 1913	$2704.93
		One-third running expenses of library, May 1, 1912 to May 1, 1913	153.76
		Books	1105.44
		Subscriptions	151.63
		Insurance	71.48
		Binding	352.46
		Miscellaneous	18.08
			$4557.78

STATISTICS OF LIBRARY MAY 1, 1913.

Source	Volumes	Pamphlets	Valuation
Report of May 1, 1913	16,141	1512	$32,660
Purchase	357	16	1,051.75
Gifts and exchanges	327	112	682.00
Old material accessioned	14	12	31.00
Unknown	4		8.00
	16,843	1652	$34,432.75

In the following table are given the figures for the total valuation of the Library property:

Books	$34,432.75
Stacks	1,761.05
Furniture, catalogues, cases, etc.	376.00
	$36,569.80

Library Attendance

		Day	Night	Total
May,	1912	641	269	910
June,	"	519	213	732
July,	"	638	closed	638
August,	"	561	"	561
September,	"	585	146	731
October,	"	566	204	770
November,	"	669	215	884
December,	"	713	214	927
January	1913	640	247	887
February	"	674	232	906
March,	"	655	275	930
April,	"	806	265	1071
Total May 1912-April 1913		7667	2280	9947
Total May 1911- April 1912		8601	2747	11348

The income from the C. O. Mailloux Fund, amounting to **$1000**, has again been used to maintain the four important sets which were presented to the library by Mr. Mailloux.

Respectfully submitted,

Frederick Bedell
Philander Betts
Dugald C. Jackson
Malcolm Mac Laren
Samuel Sheldon, *chairman.*

EFFECTS OF ICE LOADING
ON
TRANSMISSION LINES

BY

V. H. GREISSER

Presented under the auspices of the

Papers Committee for the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

EFFECTS OF ICE LOADING ON TRANSMISSION LINES

BY V. H. GREISSER

Abstract of Paper

Wires hung from suspension insulators do not maintain their relative positions as closely as when pin type insulators are used, owing to the deflection of the insulators with unequally loaded spans. During the winter season a transmission line of the Washington Water Power Company was rendered almost useless due to short circuits caused by the stretching and sagging of the wires when unequally loaded with ice, which falls from some spans sooner than others.

A series of tests upon an experimental line was made to determine (1) the influence of the loaded line upon the elasticity of the cable; (2) the effect of swing of insulators; (3) the effect of using strain insulators at short intervals, and (4) the combined effect of these conditions.

The manner of making the tests is described and the results are shown graphically.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., September 9-11, 1913.

EFFECTS OF ICE LOADING ON TRANSMISSION LINES

BY V. H. GREISSER

In a number of papers on transmission line subjects, which have been presented before this Institute, mention has been made of the fact that wires hung from suspension insulators did not maintain their position in the same manner as when pin type insulators were used. It is assumed that this fact has not been sufficiently covered to show the importance of such change of condition of equilibrium, and therefore a record of actual experience and tests may prove of interest to engineers and operating companies. A brief description of the tower line experimented with will assist in making the subject clearer.

In the latter part of 1911, The Washington Water Power Company, of Spokane, Washington, finished the construction of, and placed in service, a double circuit tower line about 28 miles (45.1 km.) long, between its Little Falls power station and the high-tension, step-down substation near Spokane.

The type of tower used is shown in Fig. 1, and it is to be noted that the conductors on each side of the tower were spaced seven feet (2.13 meters) from each other in a vertical plane. Each conductor was a nineteen-strand, 270,000-cir. mil (136.8 sq. mm.) aluminum cable. Two $\frac{3}{8}$-in. (0.953 cm.) diameter extra galvanized Siemens-Martin steel cables were attached to the top of the towers for lightning protection, and it was interesting to find, during tests on a tower, that these cables also have a very great effect in adding stability to the construction of the line as a whole. Each cable was suspended from the ends of the crossarms by means of four 10-inch (25.4 cm.) diameter insulator units as shown in Fig. 2, the length of the

complete insulator and cable clamp being $34\frac{1}{4}$ inches (87 cm.) from the center of cable to the eye at the end of the crossarm.

The cable clamp (also shown in Fig. 2) consisted of two pieces of treated hardwood with companion grooves in which

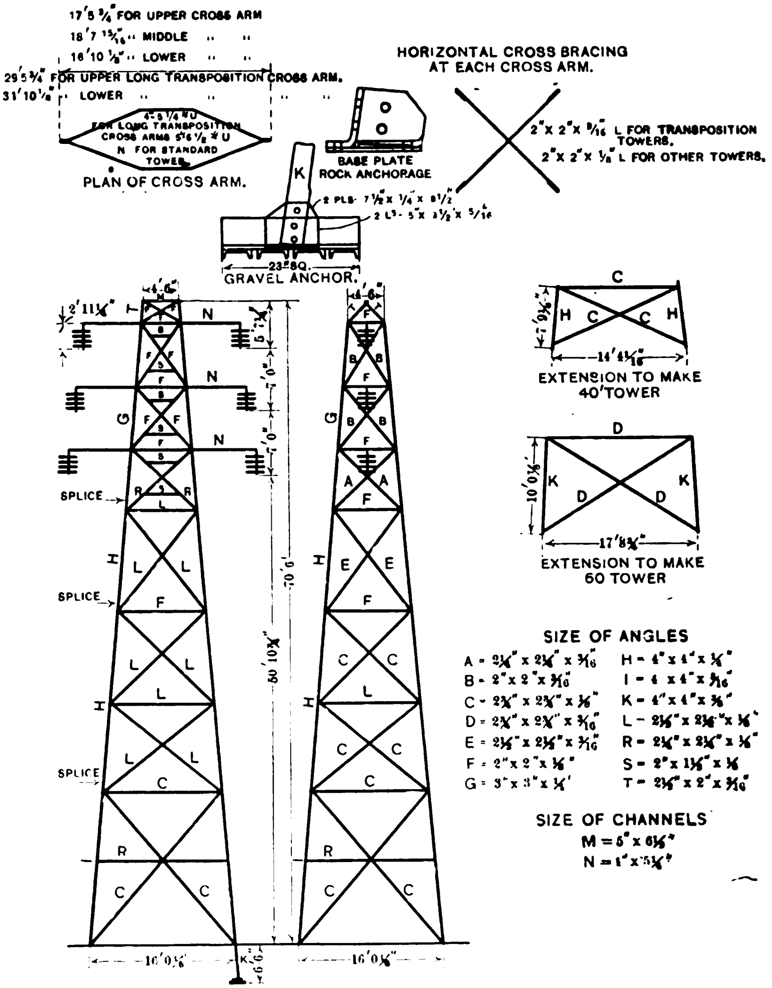

FIG. 1—STANDARD TOWER.

the cable was clamped as shown in the drawing, the hardwood being used in contact with the aluminum, to prevent any abrasion after the clamp was tightened.

An arcing rod $\frac{1}{4}$ in. (0.635 cm.) square was placed in a groove

on the upper side of the top half of the wooden clamp, this rod being intended to act in protecting the cable in case an insulator flashed over. There have been so few of such insulator flash-overs up to this writing that no extended data are available as to the usefulness of the arcing rods, but in the cases in which flash-over occurred, the cable was protected from in-

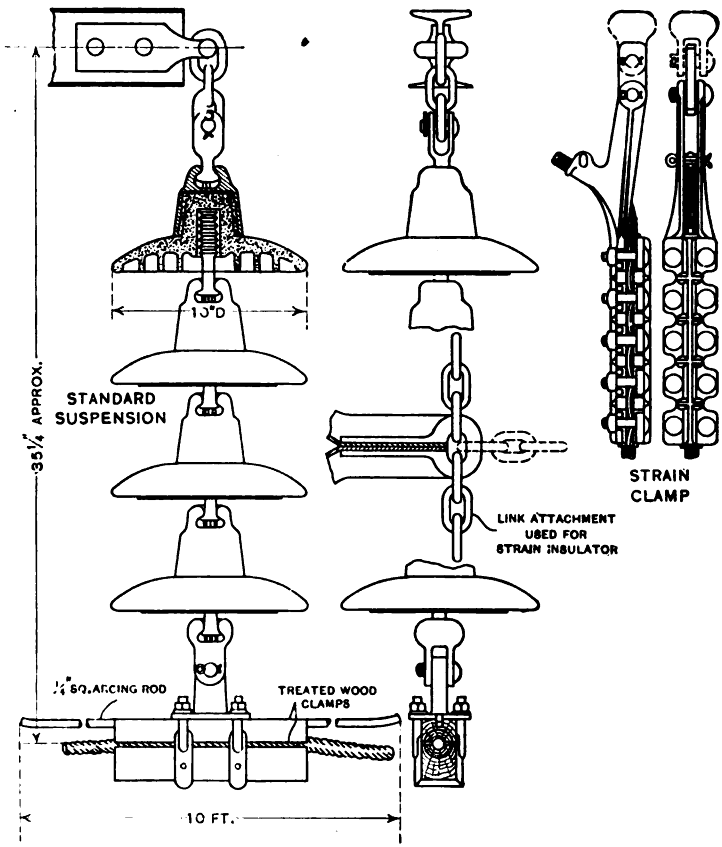

FIG. 2

jurious pitting or burns. A small strip of sheet aluminum was used to connect the cable to the metal parts of the clamp and lower insulator unit to prevent burning or digesting of the wooden parts.

The standard span was 750 feet (228 m.), but in 26.52 miles (42.7 km.) of actual tower line, 225 towers were used, making an average of about 625 feet (190 m.).

The heights of towers, weights and number used were as follows:

Height to lowest suspension from ground stub	Number used	Weights without footing
40 ft. (12.2 m.)	10	4315 lb. (1960 kg.)
50 " (15.2 m.)	189	5324 " (2420 ")
60 " (18.3 m.)	10	6390 " (2890 ")
50 " (15.2 m.)	16	6467 " (2930 ")

The last 16 towers enumerated above were transposition towers.

All the material of towers, insulators and conductors was tested and inspected at the factories.

This line was put into operation without trouble, and operated thus until about the middle of December, 1911, when numerous short circuits occurred without any apparent cause. Regular patrol had been maintained, but during a few days of fog and frost conditions the short circuits occurred so frequently as to make the line almost useless. Though a large number of men were almost continuously along the line, it was some days before the cause of the trouble was located, in fact not until the trouble had ceased could enough evidence be accumulated to show the real cause.

It was then found, during the fogs, when hoar frost and ice formed on the cables, that, upon the weather becoming warmer, the frost and ice would fall from the cables, but not from each span at the same time, and the loaded spans would increase their sags and at the same time decrease the sag in adjacent spans and deflect the suspension insulators until a new condition of equilibrium was established, which caused short circuits between wires. A test was made to show this fact, by loading the bottom wire of one span with seven bags of rock equally spaced and which fairly represented the load of ice that had been known to accumulate upon the cables.

The effect upon the loaded span and the adjacent spans was rather startling, since the loaded span sagged down to within 13 ft. (3.96 m.) of the ground, the increase in sag being approximately 20 ft. (6.1 m.) in a span 733 ft. long (223 m.).

The bottom cables of unloaded spans at either side became more taut, and thus reached a position within two inches (5.08 cm.) of the middle cable at the centers of those spans, the middle

cables being normally seven feet (2.13 m.) above the bottom ones.

The insulators supporting the loaded span were deflected about 50 degrees towards it.

Thus it will be seen that any span on which the heavy ice load had not dropped, and which had adjacent unloaded spans, would probably short-circuit a line with vertical spacing of wires as described above.

A number of observations were made on the line when sleet, snow or frost was on the cables, and the unstable conditions of the spans observed were so startling that it was decided to make a series of tests to determine what the principal features were that produced the changes in sag.

It was desired to ascertain:

First. The influence on the loaded span of the elasticity of the cable.

Second. The effect of swing of insulators.

Third. The effect of using strain insulators at frequent intervals.

Fourth. The combined effect of the above conditions.

These tests were made over what was considered at the time a rather large range of equivalent ice loading, but subsequent information shows that weights of ice greater than the maximum used in these tests must be provided for, in designing lines for some localities.

Reference to Fig. 3 will show the experimental line constructed. A level stretch of ground was selected and five spans of line were erected, using six 60 ft. (18.3 m.) cedar poles 750 feet (228 m.) apart in a straight line.

Heavy crossarms were attached at the top and spaced seven feet (2.13 m.) to reproduce the same spacing of arms as on the steel towers. Four units of the disk insulator type were attached to the ends of the arms, these units giving identical suspension with that on the towers. The insulators weighed about 46 lb. (20.9 kg.).

Aluminum cables of 270,000 cir. mils (136.8 sq. mm.) section (the same as on the towers) were then strung on the insulators, the ends being dead-ended at the first and sixth poles. This cable weighed approximately 1315 lb. (595 kg.) per mile (1.61 km.), with an average ultimate strength of 24,000 lb. (10,900 kg.) per square inch (6.45 sq. cm.) and an elastic limit of approximately 14,000 lb. (6350 kg.) per square inch (6.45 sq. cm.).

The heights of towers, weights and number used were as follows:

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The cable was strung according to a temperature-tension curve based on a maximum condition of stress of -30 deg. fahr. (-34.4 deg. cent.) with $\frac{1}{4}$ in. (0.635 cm.) of solid ice around the cable and with a 60-mile (96.5-km.) (actual velocity) wind blowing at right angles to the line. Under this condition the cable would be stressed to the elastic limit as given above.

The crossarms and poles were rigidly guyed, with turnbuckles in the guys to maintain poles and arms in a constant position.

Marker poles were set up at the center of each span to measure the sags and changes in sags. Transits were used to determine any movement of arms or poles.

During the tests described below the temperature ranged between 58 deg. fahr. (14.4 deg. cent.) and 72 deg. fahr. (22.2 deg. cent.), but the influence of this change of temperature

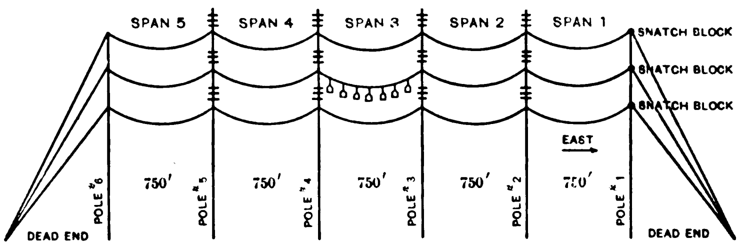


FIG. 3—EXPERIMENTAL LINE CONSTRUCTED NEAR JAMIESON, WASH., TO DETERMINE THE EFFECT OF ICE LOADINGS ON LONG SPANS OF ALUMINUM WIRES, USING SUSPENSION AND STRAIN INSULATORS.

was found to be so small as to be beyond the accuracy of the test. No wind was blowing at the time of taking readings.

To reproduce as nearly as practicable the condition of ice loading on the conductors of the steel tower line, seven concentrated loads were hung from the conductor, equally spaced in the span.

This is not an exact representation of ice load on a cable, yet loads so spaced would give results comparable with those under operating conditions, since it has been observed that ice or sleet forming on wires does not do so with mathematical uniformity.

The vertex of the span is shown plotted in the curves, and is measured on all three cables from the same common point.

It is also to be remembered in this connection, that the three conductors were normally seven feet (2.13 m.) apart in the vertical plane.

First Test. The middle cable in span 3 (see Fig. 3) was loaded with various amounts to represent ice loading. The sags of each span, insulator deflections, and the distance were measured from the nearest pole to the point where the middle cable crossed the cable below.

This is equivalent to having strain insulators every five spans with ice loading on the middle span and with the other spans bare.

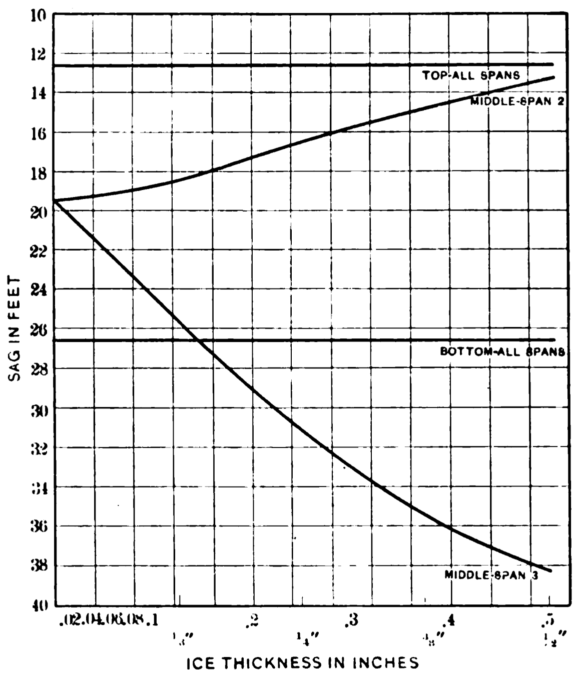


FIG. 4—FIRST TEST.
Middle wire in span 3 loaded.

The results are plotted in Figs. 4, 5 and 6.

Second Test. The middle cable in span 1 was loaded, this being a test having the equivalent of a strain insulator at one end of the span.

This test shows the different deflections of insulators and sags, and gives an idea of the decreasing effect in the spans out along the line. Curves in Figs. 7, 8 and 9 apply to this test.

Third Test. All tension on the middle cable in spans 2 and 4

affecting span 3 was taken out, and the insulators on poles 3 and 4 were allowed to swing towards span 3.

This test shows the great increase in sag due to swing of the insulator alone, and a further increase of sag (but of comparatively small amount in proportion) due to the elastic properties of the wire.

Reference to curves in Figs. 10, 11 and 12 will show the results.

Fourth Test. Strain clamps were placed on the ends of the

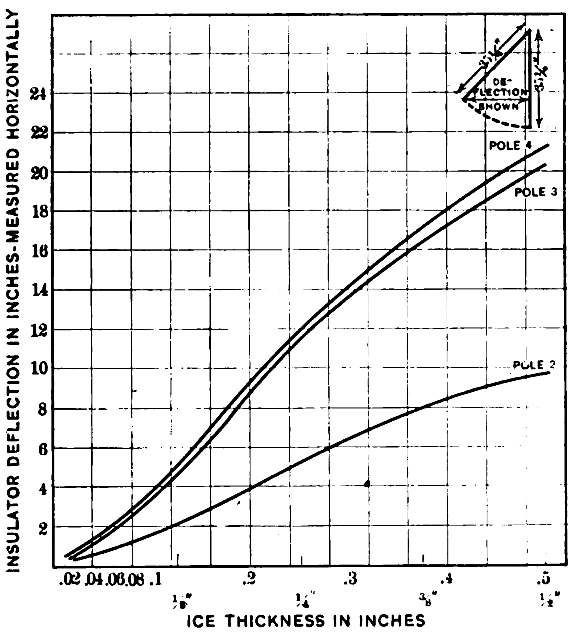


FIG. 5—FIRST TEST

Middle wire in span 3 loaded. Curves show deflections of insulators holding middle wire.

middle cable in span 3, and therefore the various loadings applied showed the effect of the elastic properties of the cable alone.

Fig. 13 covers this test.

The results of the above tests showed that for this particular tower line, its combination length of spans, size and material of wire, and the character of weather conditions, called for a change in arrangement of conductors from the vertical plane. Therefore the point of attachment to the crossarm of the top

insulator was moved in towards the tower, the middle cross-arm lengthened and the attachment to the bottom arm left as originally constructed.

The conductors were then no longer in a vertical plane, and one winter's experience has shown no short circuit, though the horizontal clearance between vertical planes through the cables is not as much as would be provided on a new tower.

The conclusions to be drawn from this experience are more

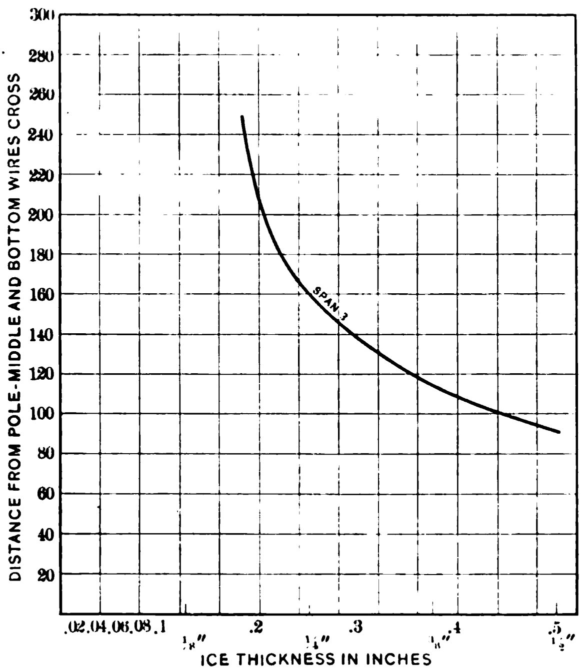


FIG. 6—FIRST TEST
Middle wire in span 3 loaded. Bottom wire unloaded.

than simply the advisability of changing wires arranged in a vertical plane, since it is also a fact that with long spans and wires arranged in a horizontal plane, although the conductors will no longer cause short circuits, they will nevertheless sag down within unsafe distances of the ground.

Therefore, in designing a transmission line with suspension insulators, a more careful examination should be made of *all* the mechanical features of the construction under consideration.

It is obvious that the length of span should be adjusted to

the material and size of the conductor, to the weather conditions experienced or expected, the voltage of the line, and therefore the length of the suspension insulators. The question of right of way also must be considered, and the final test of the allowable amount of expenditure for the service to be performed by the line, will set the limits of construction.

Since a conductor should be strung with due regard to the maximum stress at low temperature, ice and wind loading (as estimated from records in the district where a line is to be

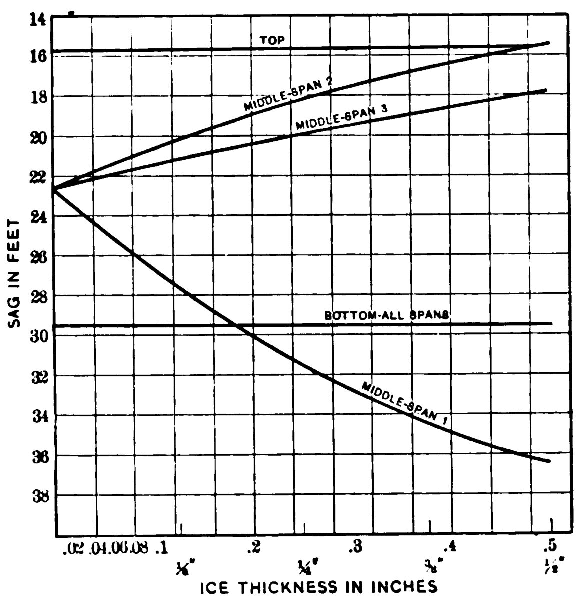


FIG. 7—SECOND TEST
Middle wire in span 1 loaded.

constructed), it is plainly desirable that a conductor having the highest elastic limit should be selected.

If the electrical characteristics of high strength steel cable and its price made it worthy of consideration, it should be obvious that the steel cable could be strung in such a flat catenary that the loading of ice on one span with adjacent spans unloaded, would not cause very much transference of sag to the loaded span.

The use of such cable would of course require strain insulators at suitable points to maintain its position, especially at places

where change of grade occurred. The use of steel-cored aluminum or steel-cored copper, or of bimetallic cable composed of steel wires surrounded by copper, and hard drawn copper of the highest strength, can all be considered with reference to the length of span and sag when using suspension insulators.

The tests described show the great influence of length of insulator on the increased sag, and it appears that notwith-

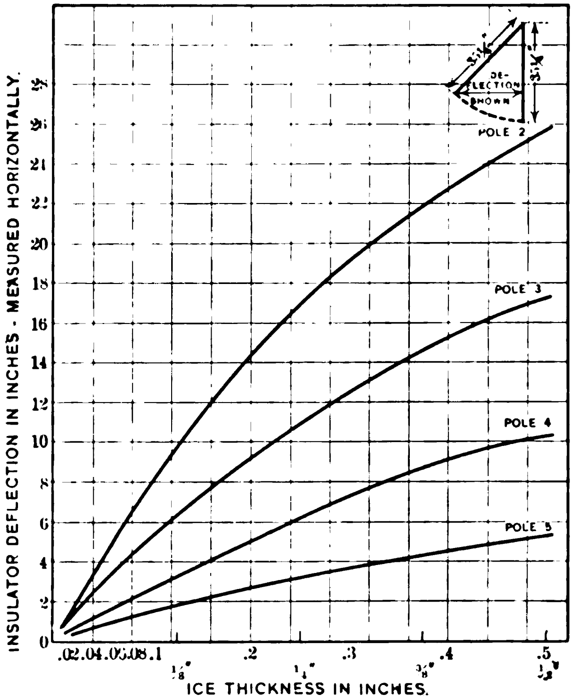


FIG. 8—SECOND TEST

Middle wire in span 1 loaded. Curves show deflections of insulators holding middle wire.

standing the great advance made by insulator designers in bringing out the suspension type, definite endeavor should be made to shorten up the insulators as much as is practical, especially for high-voltage work, where long length of insulators and small light-weight conductors both tend to aggravate the effects shown in this paper.

One of the most difficult features to consider is that of weather

effects, especially the simultaneous conditions of low temperature, ice or sleet and wind. This is especially true in the West, where Government weather stations are not located near each other, and where the district to be traversed by a line is sparsely settled. There is then no fund of information on which to draw, and the general judgment of the engineer must be relied upon. The engineer should inform himself on the method of formation of sleet and frost, and as to the general topography of the surrounding district, and the source and direction of

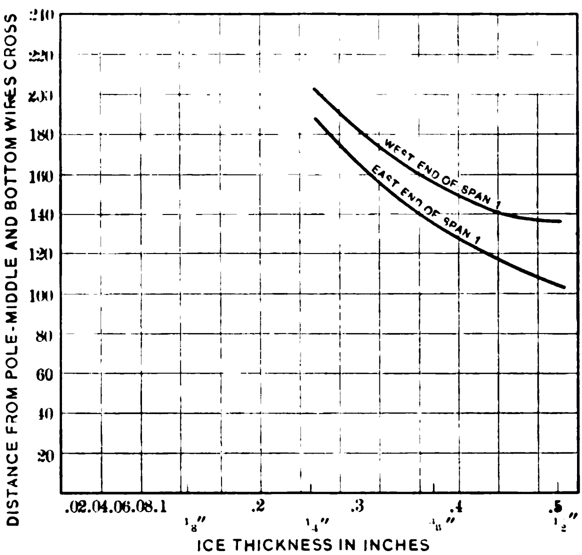


FIG. 9—SECOND TEST
Middle wire in span 1 loaded. Bottom wire unloaded.

travel of the storms which will reach the line. Such general information can usually be secured.

In the case of the tower line described above, it can be stated that the line runs in a northwesterly direction from Spokane, and is at an average altitude of about 2000 feet (610 m.) above sea level.

Two specific kinds of trouble were experienced, one due to very heavy hoar frost being deposited by fogs from the Columbia River valley to the southwest, and which melted rapidly as the fog lifted and the sun came out, this melting usually occurring on the different spans at different rates.

The other weather effect was the deposition of wet snow driven by a hard wind from the southwest, approximately at right angles to the line. This wet snow load sometimes froze solid and was of unusual shape. The outside contour of the snow was approximately that of a flattened ellipse with the conductor at one focus, the snow adhering and piling up on the windward side of the conductor, but not on top. It has

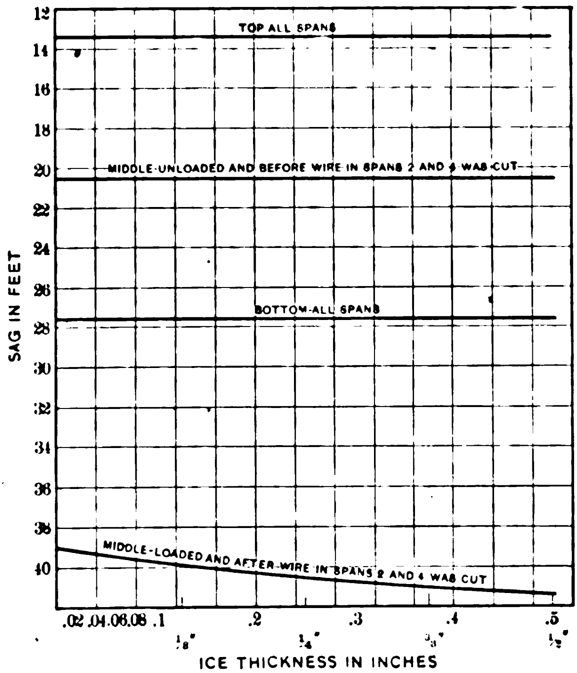


FIG. 10—THIRD TEST

All tension in the middle wire in spans 2 and 4 was taken out and the insulators on the middle wire in span 3 allowed to swing toward span 3. Span 3 was then loaded. This was equivalent to cutting the wires in spans 2 and 4 near the insulators at poles 3 and 4.

also been found that heavy fogs would deposit in the same manner.

Authentic reports on ice loading of telephone and high-tension wires in this district show that the dimensions of such deposits have been about 1½ inches (3.81 cm.) in the vertical plane by 3½ inches (8.9 cm.) in the horizontal, on a No. 9 B.w.g telephone wire, the weight per foot (0.3048 m.) of deposit being 0.8 lb. (0.363 kg.), all by actual measurement.

In another case of a No. 0 aluminum cable, the dimensions of the deposit were 1¾ inches (4.45 cm.) thick by 6 inches long (15.2 cm.).

The outside surface of such deposits is very rough and it is useless to use the ordinary formula in calculating wind pressure, as the surface is more nearly that of a plane than a round smooth wire or stranded conductor.

In the cases of wet snow deposits, a high wind usually accompanied the snow, with the temperature around the freezing point.

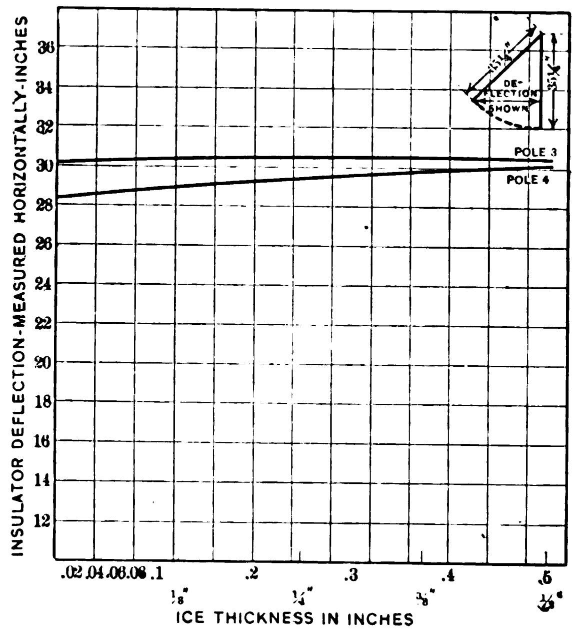


Fig. 11—Third Test

Curves show deflections of insulators holding middle wire in span 3.

Financial considerations will generally limit the reduction of length of span, but a carefully made total cost curve of different tower spacings will frequently show that the cost over a wide range of spacing is very nearly constant. This is especially true if the proper allowances are made on cost of towers, etc., for the different spacings. In such cases, some consideration should be given to the smaller maintenance expense and

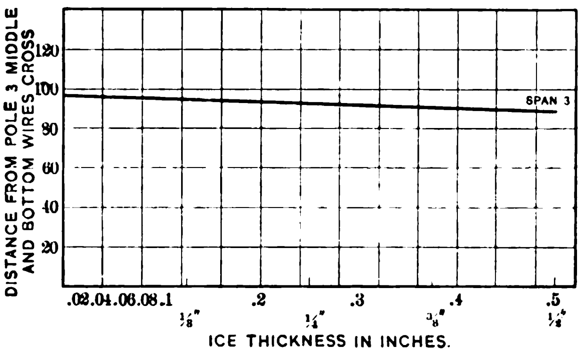


Fig. 12—Third Test

Bottom wire unloaded.

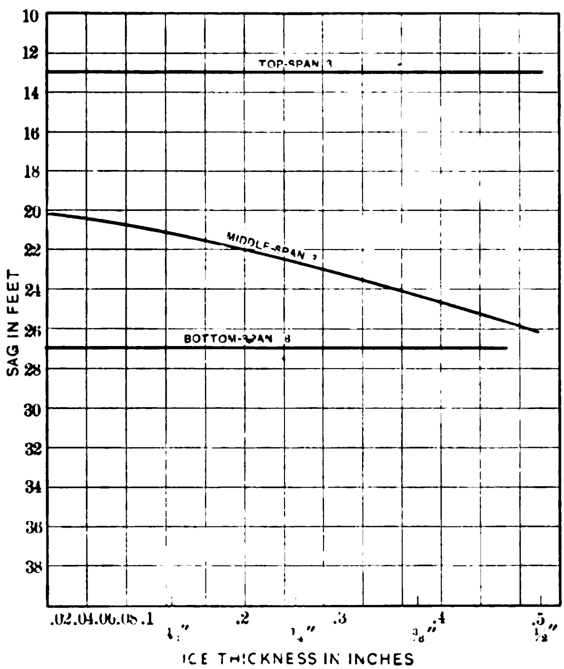


Fig. 13—Fourth Test

Strain clamps were placed on the middle wire in span 3 and the wire fastened solidly to the crossarms. Span 3 was then loaded. This was equivalent to a line with strain insulators at every tower.

more reliable operation of the shorter spans, and the final tower spacing chosen with all these facts in mind.

It is hoped that this paper will not be construed as condemning long spans or suspension insulators, for such is not the intention, but is desired to show that transmission lines should be built with due regard to *all* the stresses which will develop in the supporting structures and conductors, if good service and low maintenance and operating costs are desired.

LOGGING BY ELECTRICITY

BY

E. J. BARRY

Presented under the auspices of the

Papers Committee for the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

LOGGING BY ELECTRICITY

BY E. J. BARRY

ABSTRACT OF PAPER

The paper describes the electric logging engines installed in a timber district in Idaho, and gives the results of tests of these machines. The carrier system is known as the "skyline" system, which is especially adapted to steep hillsides, and as the logs are carried with only one end trailing on the ground, rock and gravel do not become embedded in the bark, thus avoiding disastrous results to the saws in the mill.

The estimated saving of the electric over steam operation for this installation is at least 50 cents per 1000 log-feet, and the electric drive also embraces many collateral advantages which are enumerated.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., September 9-11, 1913.

LOGGING BY ELECTRICITY

BY E. J. BARRY

In October of last year the Potlatch Lumber Company, of Elk River, Idaho, placed in service two electric logging engines, and from the results obtained, it is confidently anticipated that these will prove the forerunners of many similar installations in all countries where logging operations are carried on. Recently the writer was able to make a test on these machines and the results are given in the hope that they may be of interest to engineers in general.

The logging engines were especially designed and built for electric drive, for use with what is known as the McFarlane skyline system. The McFarlane system is especially adapted for use in country where the logs have to be removed from steep hillsides. A 1½-in. (3.8 cm.) steel cable is anchored to standing timber on the crest of the hill, the other end being fastened to the hoisting drum of the donkey. This cable may be carried out a distance of 4000 ft. (1219 m.) under favorable conditions; that is to say, where the weight of the trailing logs will not cause too great a sag.

A carrier or trolley attached to an endless line brings in the logs, clearing the entire hillside within the limits of its travel.

When one portion has been cleared the main cable is moved to a new location, and so on until a radius of from 3000 to 4000 ft. (914 to 1219 m.) has been cleared of timber. The logging engine may remain in one place for two or three weeks and thus save the expense of moving continually, which the older method of ground haulage involves. Also the logs are in much better condition for the sawmill when they have not been hauled bodily over the gravel and rocks. Pieces of gravel in

the latter case are embedded in the bark with disastrous results to the saws when they come in contact with them.

The skyline method permits of much faster handling, as the logs, having only one end trailing, are not likely to encounter obstacles.

The electrical equipment of each machine consists of one 150-h.p., 550-volt, 600-rev. per min., 60-cycle, three-phase wound-secondary logging type motor, equipped with a solenoid brake. The motor is totally enclosed and of very substantial construction to withstand the exceedingly hard service the work involves. The control consists of a seven-point controller connected to a bank of resistance grids located in the rear of the skids on which the machine is mounted. The controller also operates the primary circuit, making the drive self-contained.

As a safeguard a time element oil circuit-breaker switch is also installed, together with an ammeter mounted in view of the operator, who is thus able to determine the safe stresses he can place on the steel cable. In practise it has been found that the cable is the weak link in the chain, the motor being able to take care of any and every load applied so far.

The brakes are operated by air from a compressor driven by a 7½-h.p. motor. Compressed air also operates the signal whistle, a very important feature of logging equipments, as in most cases of long haulage the operator cannot see the load on starting, but must depend on signals, given by the hook tender, as to what he has to do.

Power is transmitted at 11,000 volts from the sawmill power plant located 3½ miles (5.6 km.) from the present logging operations. Portable substations mounted on flat cars, as shown in the illustration, step the voltage down to 600. Power is then supplied to the motors by triple-conductor No. 000 cable, steel armored, and lead covered. Expulsion fuses and horn-gap arresters protect the primary side of the 200-kw. three-phase oil-cooled transformers.

The line construction has been made as simple as is compatible with safety, and inclusive of all charges, clearing right of way, material and labor, but cost of land not included, amounted to $767 per mile.

The illustrations show the general contour of the country in which these operations are being carried on, and also why it is unnecessary to make frequent changes of location for the logging engine. In Fig. 1, the entire hillside has been cleared from the position shown.

[BARRY]

FIG. 1—GENERAL VIEW OF HOISTING APPARATUS AND LOG LOADER

FIG. 2—TRANSFORMER CAR AND LOGGING DONKEY [BARRY]

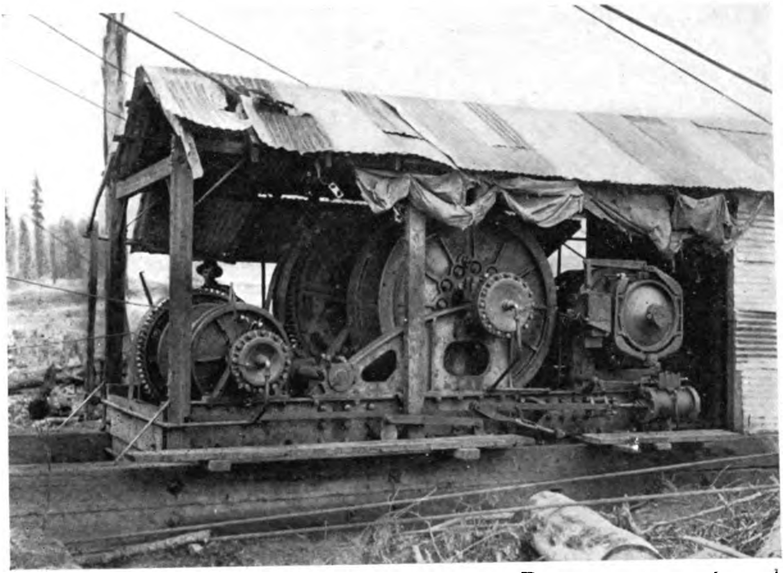


FIG. 3—MOTOR AND WINDING DRUMS [BARRY]

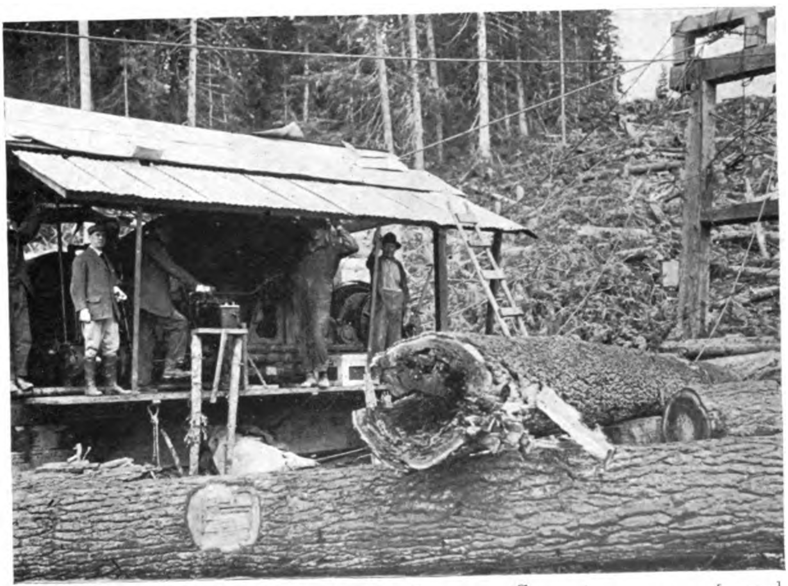


FIG. 4—VIEW OF CONTROL GEAR [BARRY]

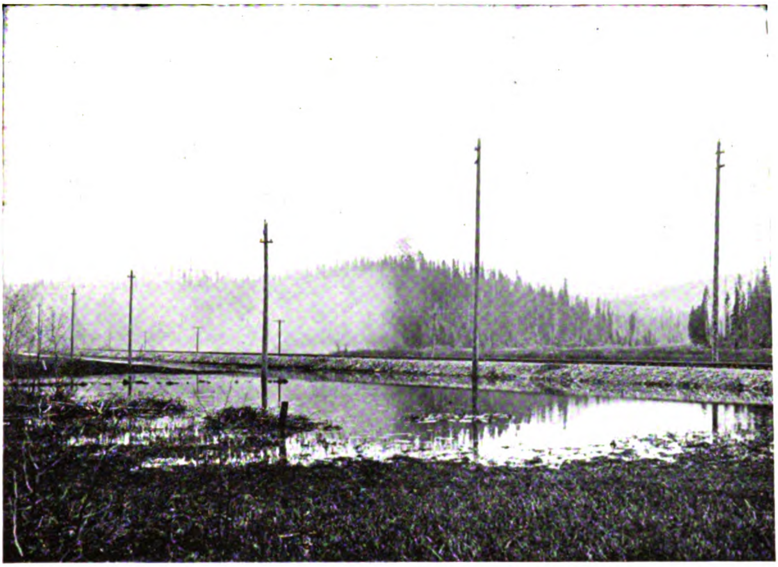


FIG. 5—11,000-VOLT LINE CROSSING THE CHICAGO, MILWAUKEE AND ST. PAUL TRACKS [BARRY]

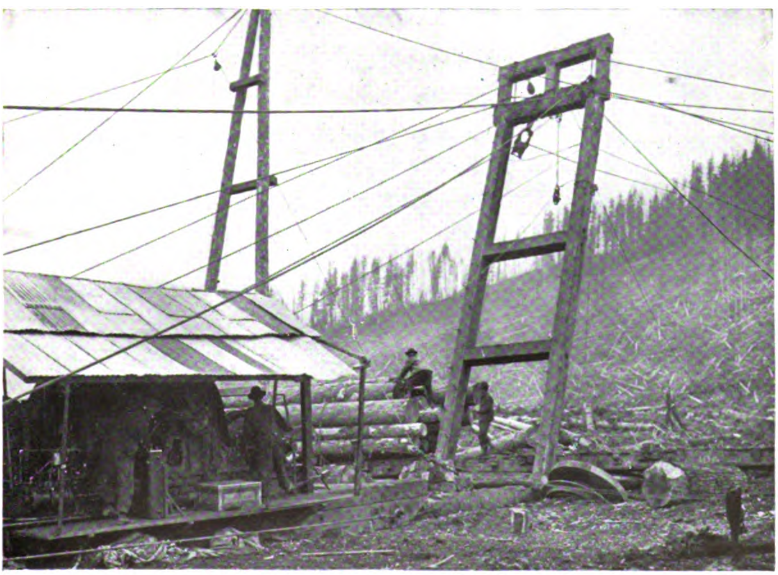
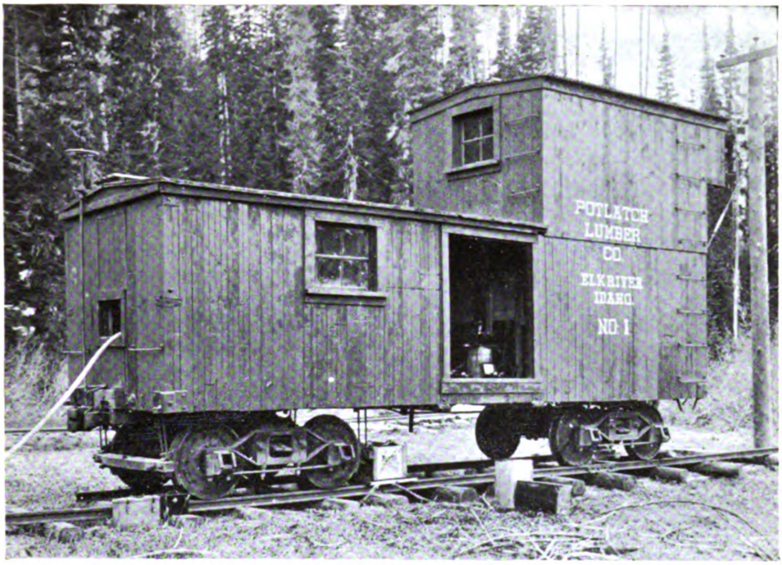


FIG. 6—LOADING LOGS ON CARS [BARRY]



[BARRY]

FIG. 7—TRANSFORMER CAR, SHOWING LOW-TENSION CABLE

FIG. 8—LOG TROLLEY OR CARRIER [BARRY]

The average daily haul for the month of April this year was 33,000 ft. (10,058 m.) for No. 1 donkey; an excellent showing, everything considered. On May 13th, the machine under test brought in 55,000 ft. (16,764 m.) of logs, establishing a record. When certain mechanical defects in the equipment have been rectified it is expected that this record will be exceeded.

The rate of travel of the trolley at present is 1000 ft. (304.8 m.) per minute hauling in an average load of 1700 log-ft. (518 log-m.). It is expected to increase this rate of travel to 1200 ft. (367 m.) per minute on the new carrier shortly to be placed in operation.

It is to be remembered that the white pine logs in this district are small compared to the fir and cedar of the Coast timber, where the distances hauled would have to be shortened considerably.

For the test, a curve-drawing wattmeter was used with an indicating wattmeter as check; an ammeter and a voltmeter were used to check power factor.

Running out light the carrier showed an average power input of 63 kw.

Hauling in logs scaling 1000 to 1500 ft. (304.8 to 457.2 m.) showed an average power input of 104.1 kw.

Loading logs on cars averaged an input of 80 kw. Power factor equaled 68 per cent, average.

A decided saving in time and power consumption would be effected by using a separate motor and light hoisting apparatus for loading and so permit loading and handling at the same time. At present the one hoist has to do duty for both operations, for which it is not suited. A 50-h.p. motor would have ample capacity for loading logs either on rollways or cars.

The advantages of electric over steam haulage can be summed up briefly:

No fuel required, with consequent wastage of good lumber averaging about 1000 ft. (304.8 m.) per day for each engine.

Elimination of fire risk in the forest.

Lower labor costs; no firemen or wood cutters required to supply fuel.

No freezing of boiler tubes in winter and consequently no charge for night watchman in cold weather.

Maintenance costs less than with steam; boilers have to be washed every two weeks and engines with reciprocating parts are harder on upkeep.

No water required. This is often a serious item, it being

necessary in many cases to pump water for a distance of two miles.

No delays to get up steam and no shut-downs through failure of pressure, a frequent happening on very long hauls.

No danger of boiler explosion.

Greater adaptability in regard to speeds, which can be increased beyond standard engine speeds at present in use.

The output of each machine can be standardized readily.

The output of steam donkeys will vary in ratio to the attention paid to proper firing.

It is estimated that a saving of at least 50 cents per thousand would be effected.

During 1911 the St. Paul & Tacoma Lumber Co., between contracts and camps hauled 81,000,000 ft. (24,688,850 m.), log scale. On combined operations the gross saving would be $40,500, from which the cost of energy would have to be deducted. Our records on the Potlatch test average 10 kw-hr. for each 1000 ft. (304.8 m.) logged. This varies somewhat, but is sufficient for practical purposes.

This 810,000 kw-hr. per year at the rate of 1.5 cents equals $12,150; and $40,500 minus $12,150 equals $28,350 saving effected, even at a minimum of 50 cents per thousand. The saving in elimination of one of the gravest fire risks can hardly be estimated in dollars and cents, but would pay a heavy interest, without any doubt.

The Smith Powers Co., of Marshfield, Oregon, will have its electric logging engines in operation this summer, when data dealing with Coast timber will be available.

The development of logging by electricity will provide a valuable load from the central station point of view, especially on the Pacific coast where transmission lines from hydroelectric plants pass through extensive logging areas. Naturally it is an off-peak load and is continuous enough to be well worth trying to secure.

Thanks are due to Mr. A. W. Laird, general manager of the Potlatch Lumber Company, for the courtesy and assistance rendered in making the test.

A MODERN SUBSTATION

IN THE COEUR D'ALENE MINING DISTRICT

BY

JOHN B. FISKEN

Presented under the auspices of the

Papers Committee for the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

A MODERN SUBSTATION IN THE COEUR D'ALENE MINING DISTRICT

BY JOHN B. FISKEN

ABSTRACT OF PAPER

The paper describes a typical mine substation built by the Washington Water Power Company for supplying three-phase power at 2300 volts to the Bunker Hill and Sullivan mine. The substation building is of structural steel which has been adopted in preference to brick on account of the ease with which it may be taken down and reconstructed as the development of the mine may require. The paper gives a detailed account of all the equipment of the substation and includes the total construction cost of the substation, the cost per kv-a. capacity, and the annual operating cost. The connected load of motors at the mine is approximately 3000 horse power. A table of distribution of cost of electric power and light for the average month is given, which shows the cost of this service for different mine operations.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., September 9-11, 1913.

A MODERN SUBSTATION IN THE COEUR D'ALENE MINING DISTRICT

BY JOHN B. FISKEN

The substation which forms the subject of this paper was put into service in November, 1910, and is the outcome of seven years experience gained by the Washington Water Power Company in distributing electric power by means of 60,000-volt lines to the Coeur d'Alene mining district in Northern Idaho.

This substation has been provided for the purpose of supplying three-phase power to the Bunker Hill & Sullivan Mining and Concentrating Company, at 2300 volts. This power is used for all purposes contingent to mining, such as running compressors, pumps, d-c. generators for mine and yard haulage, hoists, saw mills, concentrators, et cetera, and for commercial lighting in the mining towns of Kellogg and Wardner.

As an indication of the evolution of this branch of The Washington Water Power Company's business, it may be stated that when the transmission line from Spokane was put into operation in August, 1903, the substation built at that time for the Bunker Hill & Sullivan mine was equipped with one transformer of 275-kv-a. capacity, whereas the demand now requires three 650-kv-a. capacity transformers. It may be here stated that the introduction of reliable electric power has been the principal factor in making the output of the Coeur d'Alene mining district in lead today the second largest of any district in the world. And not only has this power been of inestimable value to the developed mines of the district, but on account of its low cost and its flexibility and convenience it has enabled prospects to be developed into mines, which without it would have remained dormant for many years.

The location of this substation is fortunate. It is within a distance of 400 ft. (122 m.) from the main transmission lines, which are in duplicate, the branch being provided with air switches to enable it to be connected to either main line. There is a spur from the railroad about 26 ft. (7.9 m.) from the building and at an elevation four ft. (1.2 m.) below the floor level, so that transformers, or other heavy apparatus, can be rolled off the railroad cars and into the building without having to be raised or lowered. The cooling water for the transformers comes from the mine tunnel, the portal of which is at an elevation of about 43 ft. (13 m.) above the top of the transformers. The secondary line to the Bunker Hill & Sullivan main switchboard is only about 750 ft. (228.6 m.) in length. These almost ideal conditions are not easily obtained in a rough, mountainous country.

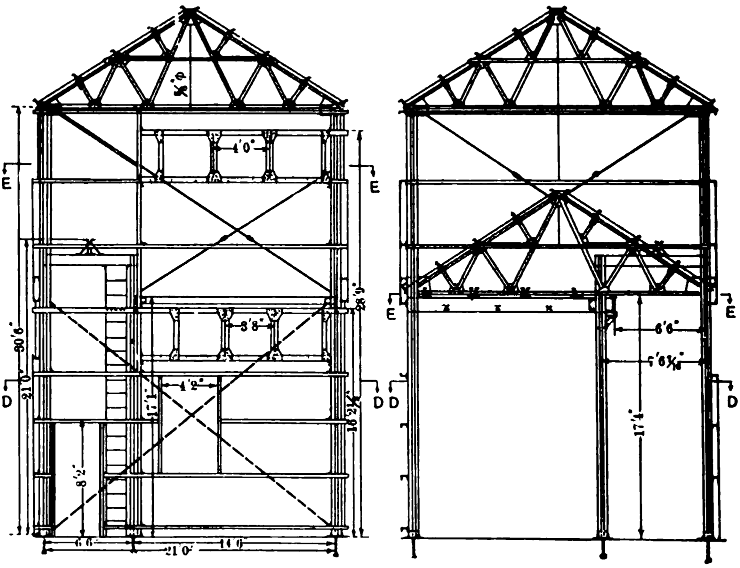


Fig. 1

The building consists of a framework of structural steel covered, both sides and roof, with galvanized corrugated iron, the main columns being supported on concrete footings. The floors are all of concrete, making the building practically fireproof. Figs. 1 and 2 show the details of the steel framework.

This type of building has been adopted in preference to brick, stone or concrete buildings on account of the ease with which it can, should the occasion arise, be taken down and reerected at some other location. The experience of the Washington Water Power Company has shown that such occasions do arise, in a rapidly growing mining country, due to consolidation

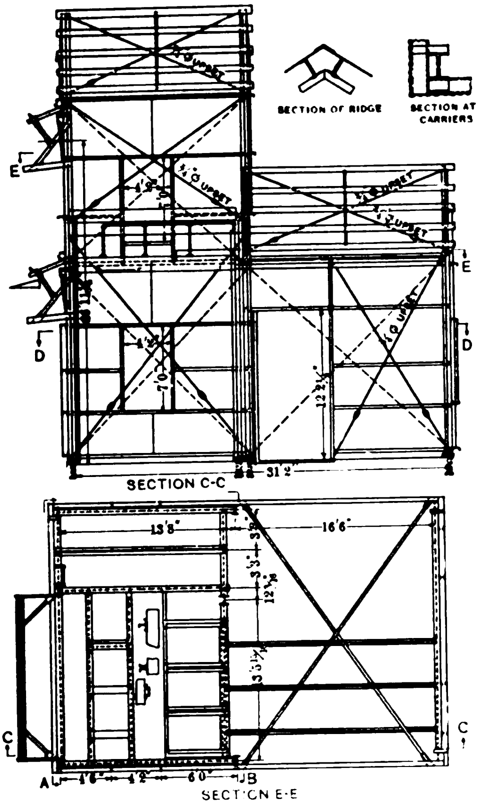


Fig. 2

of adjacent properties and centralization of the works, or to the abandonment of properties which have "played out", or, as in the case of the Bunker Hill & Sullivan mine, to the extensive development of the property.

While the steel type of substation offers no saving in first cost, it has the advantage that if it should have to be moved all that is lost of the first investment is the cost of the concrete

and labor of erection and equipment. This has been demonstrated on several occasions to the satisfaction of The Washington Water Power Company. On the other hand the salvage from a brick building is practically nothing, as the cost of taking it down and cleaning the brick is about all the material is worth. The first type of brick substation is shown in Fig. 3, and a later type in Fig. 4. The first type of steel substation, which is standard for a two-transformer station, is shown in Fig. 5, and Figs. 6 and 7 are exterior views of the Bunker Hill & Sullivan substation.

Outside the substation are located the horn gaps for the lightning arresters, and reactance coils in the supply wires as a further protection to the apparatus.

All incoming wires enter through porcelain wall-tubes set in concrete slabs. These wall-tubes were tested to 135,000 volts when subjected to a precipitation of one inch of water per five minutes without flashing over; to a potential of 155,000 volts for three minutes when dry; and immediately after the last test to a potential of 165,000 volts without flashing over. During these tests the wall-tubes were arranged with their axes in an approximately horizontal position, the connection for potential being made to a metal support in contact with the edge of the disk, and to a metal rod through the center tube.

The lightning arresters, which are of the electrolytic type, are located immediately inside the buildings. As no attempt is made to heat the building, and as temperatures as low as −30 deg. fahr. are not uncommon, it was considered advisable to provide means to keep the temperature of the lightning arresters from reaching a point which might impair their efficiency. This was accomplished by building a housing which can be heated with electric heaters. The housing consists of an open framework of scantlings covered both inside and out with metal lath and plastered with hydraulic cement plaster, the open spaces being filled with loose shavings. To permit of readily removing the arresters, portions of the top of the housing are omitted and openings are left in the front. The openings in the top of the housing are closed after the arresters are in place by means of asbestos slabs, and removable doors built of asbestos slabs strengthened with wooden framework close the openings in front. Fig. 8 shows the details and Fig. 9 gives a general view of the top of the housing with roof insulators and connecting leads of copper tubing.

[FISKEN]
FIG 3—FIRST TYPE OF BRICK SUB-STATION

[FISKEN]
FIG. 4—LATER TYPE OF BRICK SUB-STATION

[FISKEN]
FIG. 5—STANDARD STEEL SUBSTATION

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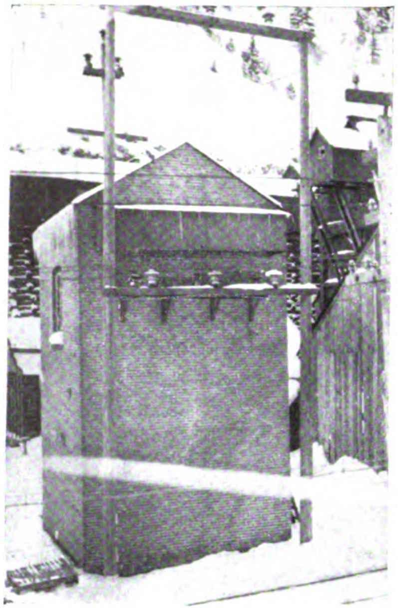
Outside the substation are located the horn gaps for the lightning arresters, and reactance coils in the supply wires as a further protection to the apparatus.

All incoming wires enter through porcelain wall-tubes set in concrete slabs. These wall-tubes were tested to 135,000 volts when subjected to a precipitation of one inch of water per five minutes without flashing over; to a potential of 155,000 volts for three minutes when dry; and immediately after the last test to a potential of 165,000 volts without flashing over. During these tests the wall-tubes were arranged with their axes in an approximately horizontal position, the connection for potential being made to a metal support in contact with the edge of the disk, and to a metal rod through the center tube.

The lightning arresters, which are of the electrolytic type, are located immediately inside the buildings. As no attempt is made to heat the building, and as temperatures as low as −30 deg. fahr. are not uncommon, it was considered advisable to provide means to keep the temperature of the lightning arresters from reaching a point which might impair their efficiency. This was accomplished by building a housing which can be heated with electric heaters. The housing consists of an open framework of scantlings covered both inside and out with metal lath and plastered with hydraulic cement plaster, the open spaces being filled with loose shavings. To permit of readily removing the arresters, portions of the top of the housing are omitted and openings are left in the front. The openings in the top of the housing are closed after the arresters are in place by means of asbestos slabs, and removable doors built of asbestos slabs strengthened with wooden framework close the openings in front. Fig. 8 shows the details and Fig. 9 gives a general view of the top of the housing with roof insulators and connecting leads of copper tubing.



[FISKEN]
FIG. 3—FIRST TYPE OF BRICK SUB-STATION

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FIG. 4—LATER TYPE OF BRICK SUB-STATION

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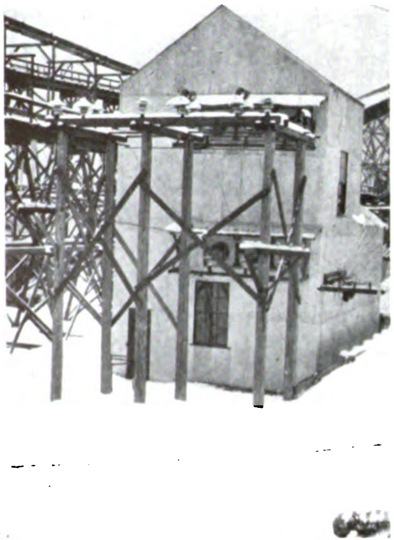
FIG. 5—STANDARD STEEL SUBSTA-TION



[FISKEN]

FIG. 6—BUNKER HILL AND SULLIVAN SUBSTATION, LOOKING NORTH

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FIG. 7—BUNKER HILL AND SULLIVAN SUBSTATION, LOOKING EAST

[FISKEN]

FIG. 9—TOP OF LIGHTNING ARRESTER HOUSING

Fig. 10 shows vertical and horizontal sections of the substation with the apparatus in position.

The main 60,000-volt conductors, which can be opened near their entrance by means of disconnecting switches (see Fig. 11), go through an oil switch to the busbars above the transformers. The oil switch is equipped with a series overload relay in each leg.

The transformers, which are run in multiple, are water-cooled,

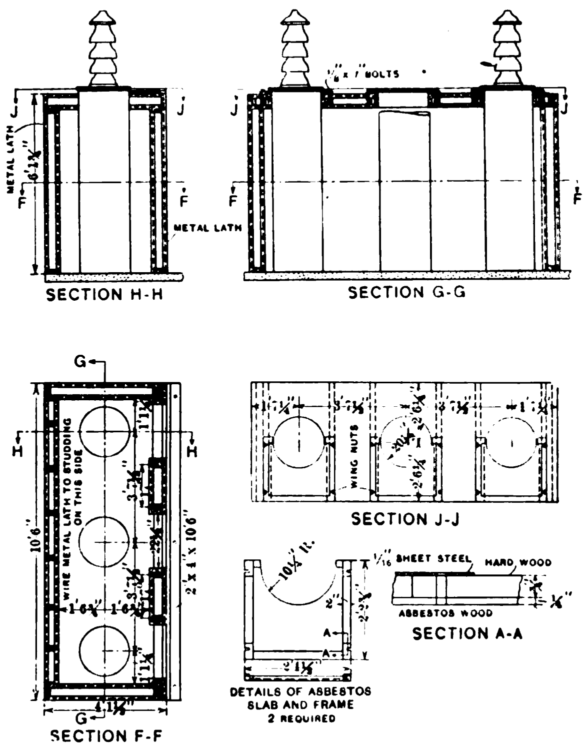

FIG. 8—DETAILS OF LIGHTNING ARRESTER HOUSING

three-phase connected, the primary in Y and the secondary in Δ, the neutral of each high-tension winding being grounded. Three transformers of 650-kv-a. each are used instead of one of greater capacity, for the reason that they were available when the station was equipped and spare transformers of that size are kept on hand; it is expected, however, that some time in the future these will be replaced by larger ones, and the building has been designed to admit of the installation of transformers

up to 2200-kv-a. capacity. The use of water-cooled, three-phase, instead of single-phase transformers was decided upon for several reasons when the first transmission line was built into the Coeur d'Alene country. The cost per kilovolt-ampere at the factory was very much less, and a considerable saving was made in freight. The economy in floor space was also a factor, not only on account of the saving in cost of the sub-

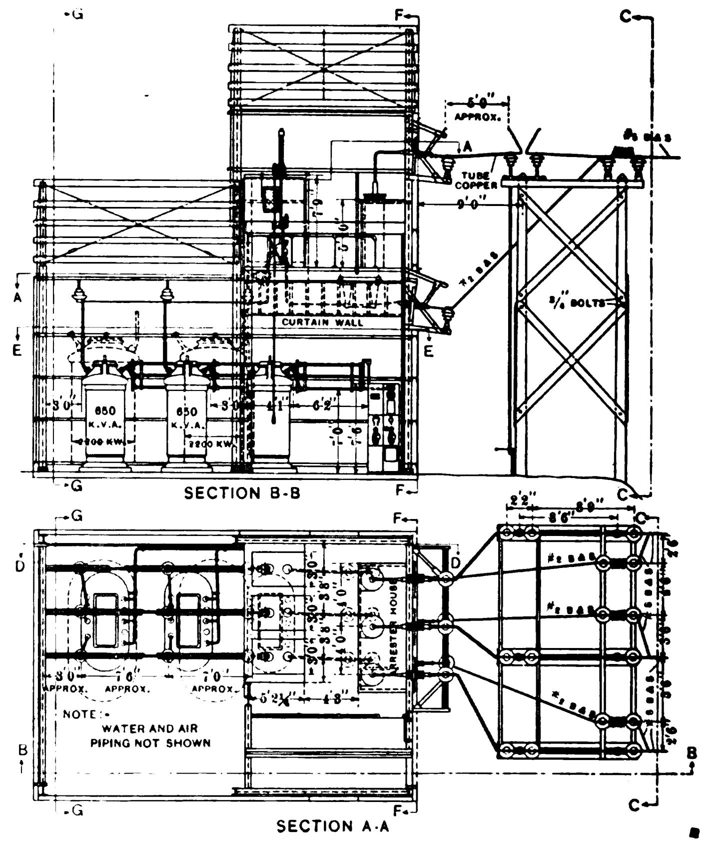

FIG. 10—SECTIONS OF SUBSTATION

station buildings, but owing to the fact that many of the substations had to be located in a canyon where every square foot of available space was valuable, while others had to be located on steep mountain sides. The Washington Water Power Company was among the first, if it was not actually the first company to adopt the three-phase transformer and the results have been such that after an experience of over ten years,

PLATE LXVIII
A. I. E. E.
VOL. XXXII, NO. 9

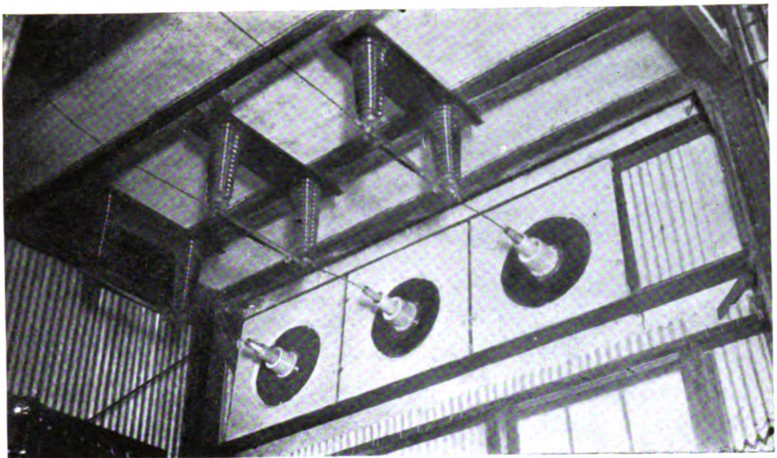

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FIG. 11—DISCONNECTING SWITCHES, 60,000 VOLTS

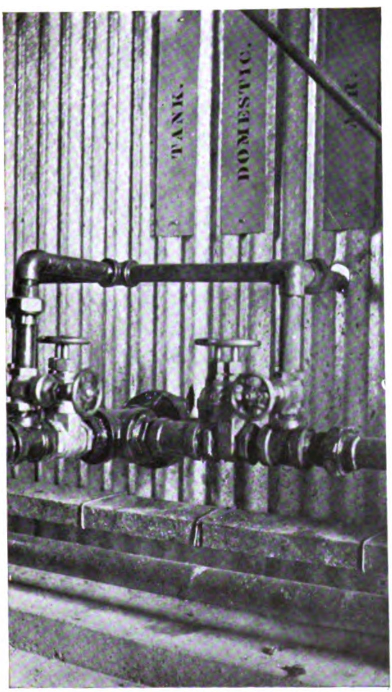

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FIG. 12—INCOMING WATER AND AIR PIPES

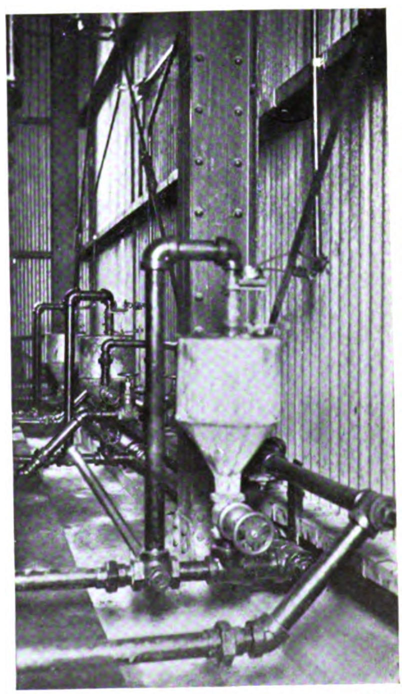

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FIG. 13—TRANSFORMER PIPING

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FIG. 14—WATER RELAY

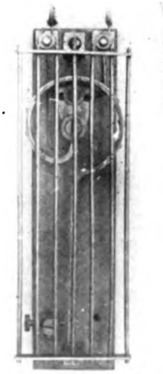

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FIG. 15—THERMOSTAT

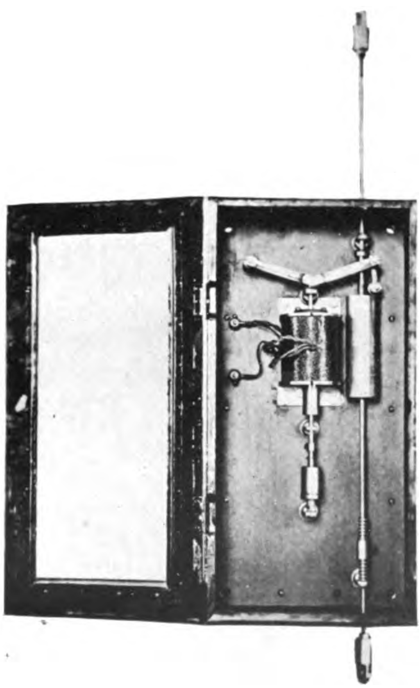

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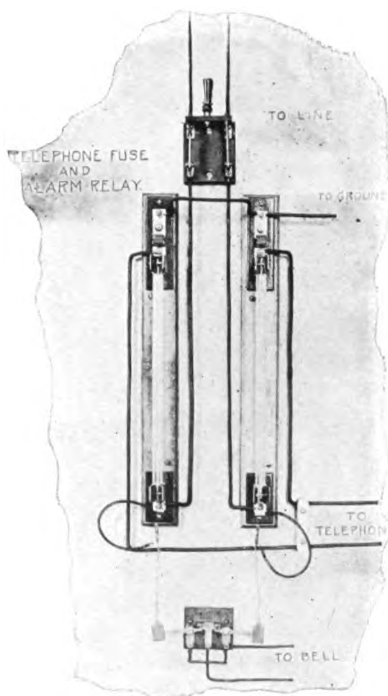
FIG. 17—AUTOMATIC TRIP



[FISKEN]
FIG. 18—TELEPHONE EQUIPMENT

not only in the company's substations but in its generating plants, it continues to purchase them.

The cooling water for the transformers is taken from the mine tunnel through a flume to a storage and settling tank, from which it is piped to the transformers. As the normal flow of water is greater than is required, the level in the tank is constant, and a low water alarm is provided to notify the attendant in the compressor room of the mine if for any reason the supply from the tunnel should be cut off. Provision is made for the use of domestic water, but in the dry, hot summer months, when the water is most required, this is very scarce and it is only used in case of emergency. As this mine water carries considerable solid matter in suspension and as all of it is not deposited in the settling tank, a permanent connection is made to each transformer from the mine air line, and at frequent intervals, what solid matter has settled in the cooling coils is blown out by air at a pressure of about 80 lb. per sq. in. (5.6 kg. per sq. cm.). Fig. 12 shows the incoming water and air pipes and Fig. 13 is a view of the piping back of the transformers.

The water is discharged from the transformers normally into the hoppers shown in Fig. 13, but can by means of a three-way valve be discharged directly into the drain pipe.

The secondary of each transformer is connected to the 2300-volt busbars, which are carried along the side of the building to the feeder switches. These switches are attached to the wall of the building and in front of them are set the controlling and instrument panels, ample working space being left between.

As will be seen, the building is arranged to admit readily of extension should the demands of the service require it, all that is necessary being to extend the side walls and roof and move the end back, no changes being necessary in the front.

For the protection of the transformers some special devices have been employed.

To prevent damage, if for any reason the supply of water should fail and the low water alarm in the tank fail to act or receive the necessary attention, a little device which is called a "water relay" is provided. This piece of apparatus, shown in Fig. 14, and as installed, in Fig. 13, consists of a beam having at one end a small bucket and at the other a balance weight which can be moved along the beam. The beam is fulcrumed so that when the bucket is full of water the combined weight of bucket and water overcomes the balance weight and raises it. A vertical rod attached to the beam moves in a vertical

plane and by means of a system of levers causes two metallic points connected electrically as well as mechanically to dip into two cups of mercury. A small hole is made in the bucket through which the water can be drained out, and two binding posts connected to the mercury cups allow for conveniently attaching the wires of the control circuit. This apparatus is mounted on the discharge pipe over the hopper and the water as it comes from the transformers falls into the bucket. This keeps closed the control circuit of which the mercury cups and contacts form a part. If for any reason the water should cease to flow through the cooling coils there would be nothing to keep the bucket supplied, and what water was left in it would run out through the drain hole, thus allowing the balance weight to fall and opening the control circuit at the mercury cups. By varying the size of the drain hole a fairly accurate time element can be introduced. As will be explained later, the opening of the control circuit at the mercury cups trips out the 60,000-volt oil switch, or starts an alarm bell ringing if the switch should fail to open. This apparatus is the result of much experimenting and has now been perfected to such a degree that absolute reliance is placed on it. It has demonstrated its value on several occasions and all water-cooled transformers installed on the system are now equipped with it, those in the substations where there is no constant attendance being arranged to trip out the oil switch, while in the other substations and power houses it calls the attention of the attendant by ringing the alarm bell.

It not infrequently happens that the water supply may be diminished to such an extent as to allow the temperature of the transformer to rise to a dangerous degree and yet prevent the water relay from operating; or an excessive overload may come on without causing the automatic switches to open. In either event the results as far as the transformer is concerned would be disastrous, and to prevent any damage from these causes a thermostat, Fig. 15, provided with suitable binding posts for attaching the wires of the control circuit, is hung in the oil above the windings. This thermostat is made by riveting together two metal strips of different coefficients of expansion and is adjusted so that when the temperature of the oil reaches 65 deg. cent. the control circuit is opened, which, as in the case of the water relay, trips out the 60,000-volt switch or causes the alarm bell to ring.

The control circuit, Fig. 16, is normally closed, is energized

by a secondary generator giving about 6 volts alternating current on the terminals and has in addition to the water relay and thermostats two modified 50-ohm telegraph relays. These relays are in multiple with each other and in series with the water relay and thermostat.

As originally installed, ordinary relays were used, the magnet coils being energized and the armatures held over against the pull of a spring so that the secondary contacts were open. It was found, however, that the constant chattering of the armature due to the alternating current was very hard on the apparatus and made the relays somewhat unreliable. This difficulty was overcome by providing the magnets with two windings of 50 ohms each, one connected in the control circuit and the other connected directly to the generator, the two windings being in opposition to each other. Thus as long as the control circuit remains closed the armature is not attracted, but should this circuit open, the remaining winding energizes the magnet, attracting the armature and closing the relay circuits or the alarm bell and the "auto trip".

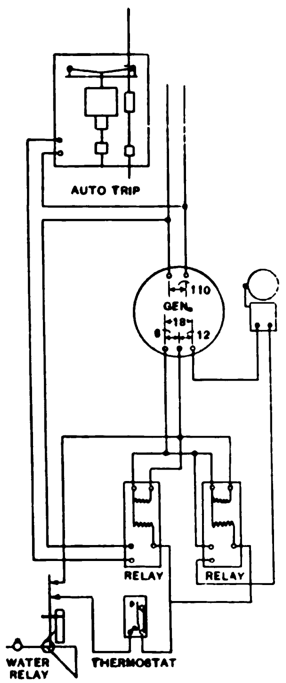


FIG. 16—CONTROL CIRCUIT

The "auto trip", Fig. 17, is a device for tripping the 60,000-volt oil switch. As previously stated, the only relays for this switch are of the series mechanical type so that no low-voltage connection could be made to them and some other arrangement had to be made.

Between the end of the hand rope which is provided for tripping the switch by hand and the switch tripping mechanism, an iron rod ¼ in. (6.3 mm.) in diameter is introduced. This rod, which is connected to the mechanism by a chain, to give flexibility without stretching, passes through the iron box containing the auto trip and at a suitable location has a collar fastened to it by a set-screw. Above the set-screw and surrounding the rod, which can be moved through it freely, is a heavy weight suspended on a dog attached to a toggle arrangement. The trip coil is located under the toggle joint so that

when it is energized the plunger, which has an adjustable dashpot to provide a time element, is pulled up, striking the toggle joint, releasing the weight and allowing it to fall on the collar which trips the switch. Owing to the iron rod being free to move through the weight, the switch can be tripped by hand at any time independent of the auto trip.

The substation is provided with a telephone connected to one of the operating lines, the equipment being temporary, to be changed later to a standard equipment. This standard equipment is shown in Fig. 18. The incoming lines connect to the lower ends of the fuses, the telephone being connected to the upper ends. The fuses consist of an alloy wire which fuses at one ampere, contained in glass tubes 14 in. long. Above the telephone connections are the lightning arresters, consisting of two carbon plates separated 0.01 inch by a small sheet of mica with a $\frac{1}{8}$-inch diameter hole in the center, the ground connections being taken from the top of the lightning arresters. As the telephone lines are carried on the same poles with the 60,000-volt line any trouble on the high-tension system induces high-voltage surges in them which go to ground through the lightning arresters and in most cases blow the fuses. An alarm device is provided which starts a bell ringing should a fuse blow; this is shown below the fuse tubes in Fig. 18. A short pivoted arm carries on one end a contact for the alarm circuit and on the other a small weight. This weight is suspended from the fuse wire by a short piece of fish line so that the alarm circuit is normally kept open, but should a fuse blow, the weight is allowed to fall, closing the contact at the other end of the arm. This alarm device is not generally used in the substations but is always used in the power houses and patrol stations. In the power houses, instead of ringing a bell a small pilot lamp is lit, which indicates at a glance which fuses are blown. In the patrol stations the value of this alarm device is inestimable. Before its introduction there were several occasions in which the fuses were blown during the night and were only discovered when the patrolman awoke in the morning. Under these circumstances it was impossible for the system operator to call the patrolman, but with the introduction of the alarm device this difficulty has been entirely overcome.

The substation is in close proximity to some valuable mine buildings, which are all wooden structures, and fear was expressed by the manager of the mine that if the oil in one of the transformers should catch fire and the burning oil boil

out of the case it would endanger the buildings. To overcome this objection the building inside is banked with concrete and drains are provided to allow the burning oil to flow into a covered cesspool large enough to hold all the oil in one transformer.

The cost of this substation was as follows:

Building (including concrete foundations and floors)	$3,733.00
Electrical equipment (exclusive of transformers)	5,003.00
Transformers installed	11,125.00
Water system for transformers	651.00
Total	$20,512.00

or $10.52 per kv-a.

The annual cost of operating the substation is as follows:

Depreciation (being the sum of the depreciation of each item and being equal to a little over 7% of the total cost)	$1,452.00
Interest at 8%	1,641.00
Taxes	77.00
Maintenance and operating (being the average of the annual cost since the station was put in service)	530.00
Total	$3,700.00

or $1.90 per kv-a.

It should be noted that the small item for operating is due to the fact that the automatic features make it possible to dispense with the services of an attendant. The substation, however, is visited every day by a patrolman who changes the charts of the recording instruments and makes a general inspection.

The maximum demand of the Bunker Hill and Sullivan Company is about 2000 h.p. and Table I shows the connected horse power of motors in the different branches of the mining operations and the percentage of the total.

TABLE I

Connected Load of Motors at Bunker Hill & Sullivan Mine

	h.p.	Per cent of total
Compressors	475	16.1
Mills	965	32.1
Hoists	200	6.7
Pumps	385	13.1
Haulage	438	14.7
Crushers	335	11.2
Other operations	182.5	6.1
	2980.5	100.0

To those who are familiar with the operation of such large mines as the one in question the percentage of motor capacity for driving compressors will no doubt appear small, but this is explained by the fact that a very large part of the air compression is done by water-driven compressors.

The motors in the mills are used for driving a great variety of apparatus and Table II is of interest as showing the different apparatus with the work done by each and the size of motor required. The daily output of the mine is about 1200 tons of ore and there are three mills available to handle it, but Table II merely gives the data of the two newer mills, as the old mill is used only to a very small extent.

The following Table III, which shows the distribution of cost of electric power and light for an average month, is of interest also as showing the cost of this service for the different operations.

TABLE III

DISTRIBUTION OF COST OF ELECTRIC POWER AND LIGHT FOR ONE MONTH

Electric power		Electric light	
Hoist	$218.40	Tramming	$41.10
Pumps	412.80	Hoisting	3.10
Mills	3100.25	Mill	25.40
Mine traction	237.74	Machine shop	0.50
Yard traction	30.40	Saw mill	0.70
Machine shop	11.65	Assay office	0.25
Saw mill	79.10	Blacksmith shop	0.25
Assay office	3.00	Yard	1.10
Compressors	299.10		
Electric light used	72.40		72.40
	$4464.84		

After more than two years' service the results from the operation of this substation have been satisfactory both to the power company and the customer. There have been some interruptions to the service but considering that the transmission line feeding this station is about eighty miles in length and runs through a rough mountainous country, this has to be expected. During the year 1912 there were fifteen such interruptions of an average duration of fifteen minutes each. The causes were various, such as lightning, limbs of trees blown into the wires, insulators broken by rifle shots and so forth. In addition there were, during the same period, about four interruptions due to trouble on some part of the mining company's installation.

In conclusion the author desires to acknowledge his obligation to Mr. Walter C. Clark, electrical engineer, and Mr. R. S. Handy, mill superintendent, both of the Bunker Hill & Sullivan Mining and Concentrating Company of Kellogg, Idaho; to the former for information given in Table III; to the latter for the information contained in Table II.

MOUNTAIN RAILWAY ELECTRIFICATION

BY

ALLEN H. BABCOCK

Presented under the auspices of the

Papers Committee of the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

MOUNTAIN RAILWAY ELECTRIFICATION

BY ALLEN H. BABCOCK

ABSTRACT OF PAPER

The paper is a study of the relative merits of steam and electric equipment for a mountain division of the Southern Pacific R.R. The two slopes to the summit of this division are 49.5 and 18.3 miles long, respectively, with average grades of 1.44 and 1.33 per cent, and ruling grades of 2.2 per cent on each slope. Assumption is made of a 2400-volt, third-rail system using 100-ton electric locomotives capable of handling train units of 500 tons for freight, and 150-ton locomotives for passenger service. On the basis of present traffic it is shown that electrification of this division would not be justified from a financial viewpoint, whether the power was " home-made " or purchased.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., September 9-11, 1913.

MOUNTAIN RAILWAY ELECTRIFICATION
A Study of the Tehachapi Pass

BY ALLEN H. BABCOCK

During the past ten years the Southern Pacific Company has investigated the question of electrification of its three outlets from the central valleys of California, north, over the Siskiyou, east, over the Sierra, and south, over the Tehachapi. The earlier reports, inspired directly or indirectly by manufacturers as a part of their propaganda program, were favorable to electrification. The railway company then began studies of the subject, independently. The conclusions of its officers were unanimously opposed to electrification, by reason of the financial results to be anticipated; however, some of its lines have been electrified, and other electric lines have been acquired for good reasons.

Lately there has been a constant and persistent pressure put upon the company officials, by both power companies and consulting engineers, to reconsider decisions adverse to electrification, decisions that were made after patient and thorough study, and in the face of the fact that to be connected with any such important engineering work as these installations would be, could but fire the professional imagination of any engineer worthy of the name. Just how much of this agitation has been due to the application of general statements regarding the benefits to be secured by electrification, to the particular problems presented by west coast mountain railroading, is hardly susceptible of direct determination. It is possible, however, that much of it is due to the effect that such hypothetical studies and papers as have been published recently, have produced upon executives, who, however skilled they may be in their specialties, only in

rare instances are sufficiently experienced technically to be capable of forming independent opinions on engineering matters. It is a fact that reports adverse to electrification in the hands of these same executives, often cause disappointment and sometimes arouse criticism.

Here, then, are two opposing parties; the one with things to sell, (apparatus, power, engineering skill), the other with a service to be maintained, at decreased cost if possible, but maintained at any cost it must be: the first reports favorably upon projects that the second considers unfavorably with equal positiveness. Some things must be unknown to both. Either the radicals have not all the facts upon which to work, or the conservatives cannot interpret their facts correctly.

Words have been multiplied with reference to the subject until aspiring authors well may pause before adding fuel, not to say fat to the fire; but it is with these thoughts in mind this paper is written, not with the intent to offer anything original in the study of such problems but to give the facts of a typical west coast mountain railroad district and their interpretation as seen by one whose reports heretofore have been responsible for many adverse decisions in such matters.

It is not intended to be the final word on the subject of electrification of this district, but it is the result of a study recently made to determine whether there was such a reasonable chance for profitable electrification as would warrant a very considerable expense in time and money, such as was incurred a few years ago in an exhaustive and final study of the Sierra problem, for example.

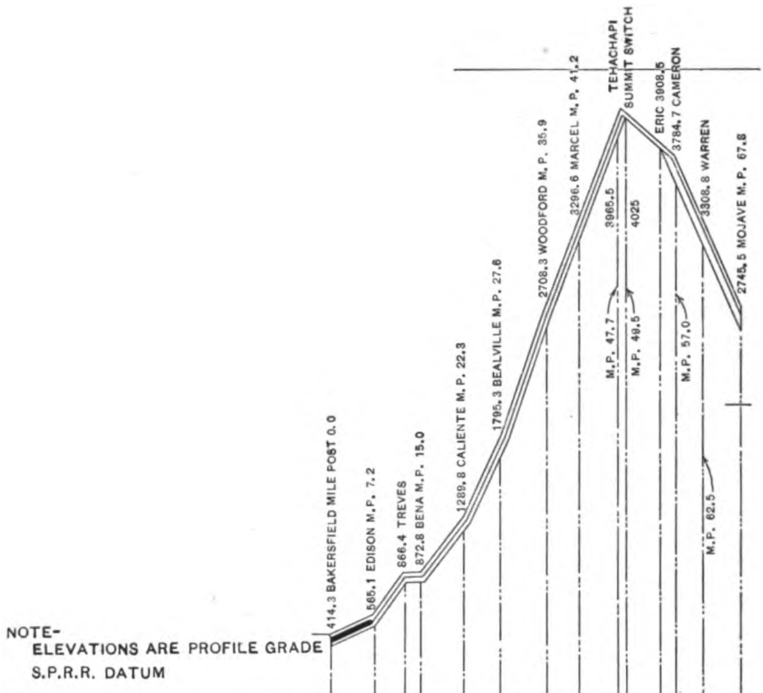
If through the facts given herein, and in the discussion thereof, a better mutual understanding will be reached, its purposes will have been served.

Physical Characteristics

West Slope, Bakersfield to Summit .... 49½ miles
- Vertical rise .... 3764 ft.
- Average grade .... 1.44 per cent
- Average curvature equal to a constant 3 deg. curve.
- Total curvature, 7944 deg., of which 6969 deg. are between Caliente and Summit (27.2 mi.). The loop curve has a total curvature of 566 deg. 33 min. 12 sec.

East Slope, Mojave to Summit .... 18.3 miles
- Vertical rise .... 1285 ft.
- Average grade .... 1.33 per cent
- Average curvature (as above) .... 0.79 deg.
- Total curvature .... 765 deg.

The ruling grade on each slope is 2.2 per cent, but these grades are not compensated for curvature so that in effect the ruling grade is 2.4 per cent. The maximum grades are long enough to fix the weight and power of the locomotives. The average distance between sidings is three miles, approximately.



MAXIMUM GRADE (FEET PER MILE)		105.6	116.16	116.16
CURVED LINE (MILES)	FROM 0° TO 6° INCL.	11.34		6.44
	" 6°01 " 8° "	2.38		
	" 8°01 " 10° "	7.67	2.63 OF 10°01 & OVER	
TOTAL ASCENTS EAST (FEET)		3686.885		5.5
" " WEST (")		76.885		1285.03
TOTAL CURVATURE		7944°		76.5

FIG. 1—CONDENSED PROFILE, TEHACHAPI PASS

In determining energy consumption of trains moving over the mountain the actual characteristics of the line were used, (see Appendix K), but in determining load diagrams and substation spacings and capacity, the following close approximations were

made to take care of the ruling grade, curves, etc. (For their application see Appendix A.)

Section	Miles	Average grade
Bakersfield to Edison	7.2	0.5 per cent
Edison to Caliente	15.1	1.5 " "
Caliente to Summit	27.2	2.4 " "
Mojave to Cameron	10.8	2.4 " "
Cameron to Summit	7.5	0.75 " "

The average freight train, eastbound, weighs 2000 tons, exclusive of locomotives. Four consolidation type locomotives, or their equivalent in Mallet compounds, are used to haul this train from Bakersfield to Summit. From Summit to Mojave one locomotive is used for supplying air for brake purposes, etc., and the other three return deadhead to Bakersfield. The westbound freight trains are lighter than the eastbound on account of the fact that much of the western movement consists of empty cars. The normal weight is 1250 tons, hauled by three consolidation locomotives, or their equivalent in Mallets; or a 1500-ton train operated by three consolidation or decapod locomotives, or their equivalent in Mallets. The helper engines cut out at Summit and return light to Mojave.

In order to provide a flexible unit it was proposed to use an electric locomotive, capable of handling a train unit of 500 tons, as many per train to be used as the weight of the train requires. The weight of the electric locomotives is assumed at 100 tons.

Passenger train weights vary from 250 tons to 600 tons, for which a single passenger locomotive weighing 150 tons was provided. A maximum freight train movement over the mountain recently consisted of twelve full-size freight trains, eastbound, and eight full-size freight trains, westbound, in addition to the normal passenger movement, which is seven regular trains each way per day, with occasional extras and second sections.

The track, particularly on the west slope, is laid for the greater part of the distance in rough country, in fact between mile posts 326 and 361 all the track, with the exception of a short stretch near Caliente, is in cuts or on fills. It may be said generally that at least half the track is laid in conditions where any overhead contact system would require, necessarily, very expensive steel pole or bridge construction. In addition to the above, there are 18 tunnels, in none of which the vertical clearance is more than 18½ ft., and 60 per cent of their total length is on 10-deg. curves. A detailed list of tunnels is given in Appendix L-1.

Experience with similar earlier reports has shown that, in general, there is little difference in total first cost and annual operating costs, whether an overhead system or the third rail system be considered. A double overhead contact system gives maximum first cost and operating costs for contact system, and minimum weights, costs and maintenance of locomotives; a single overhead contact system gives high first cost and operating costs for contact system, with maximum weights and maintenance of locomotives; the third rail gives high first cost and minimum operating cost of contact system, medium locomotive weights and first costs, with minimum operating costs, but the total costs are brought up to the level of the others by reason of the necessary substation apparatus and attendance. A choice of systems therefore is to be made only after an exhaustive study of all the local conditions.

In a preliminary study, as this is, it matters little what particular system of propulsion is chosen, upon which to base the estimates. For the purposes of this discussion a 2400-volt continuous-current, third-rail contact system was selected for the main line, with an overhead contact system in yards and terminals, at Kern, Bakersfield and Mojave.

In the following, the First Costs are based on the present traffic as shown by the train dispatcher's sheets; the Annual Operating Costs are taken from the reports of the fiscal year ending June 30, 1912, for steam operation, while the same traffic and reports are used, as far as they apply, in estimating the costs for electric operation.

FIRST COSTS

Substations,	Appendix A	$1,610,000
Generating station,	" B	1,760,000
Transmission system,	" C	430,050
Contact system (yards)....	" C	155,250
" " (line),	" A	825,000
Bonding,	" A	122,300
Block signals,	" D	175,000
Shops and inspection shed,	" E	10,000
Electric locomotives,	" F	2,085,000
Total		$7,172,600
Credit by steam locomotives released for service on other divisions, Appendix G		1,464,900
Net first cost		$5,707,700

ANNUAL OPERATING COSTS
(Steam-generated power)

		Steam	Electric
Substation labor and supplies,	Appendix A.....		$59,700
Power house labor and supplies	" B......		84,780
Transmission and contact system maintenance,	" C.....		36,576
Maintenance of way as affected by locomotives,	" H.....	$126,890	83,285
Locomotive repairs,	" I......	270,990	70,701
Loco. enginemen, (passenger),	" J.....	48,300	29,100
Fuel,	" K.....	240,852	100,530
		$687,032	$464,672
Bond interest at 4½ per cent.....................			256,847
Totals................................		$687,032	$721,519

Net loss, $34,487

In the above no account is taken of items not affected by character of motive power: freight enginemen, and all train crew wages, repairs to cars and maintenance of way as affected by cars—for example.

The net loss under proposed electric operation is so small that it might be wiped out by a reasonably small change in the assumptions; in fact, at this stage of similar investigations often there is a temptation to search for opportunities to change this, or to modify that, as the necessities of the case demand. This important fact should be borne in mind, however, that in the foregoing no account is taken of taxes and depreciation, both of which must be paid, some time, by some one, to the extent of at least 5 per cent of the net investment, which increases the net loss by approximately $285,000 per year.

It may be asked, why is depreciation not taken into account in the usual manner? The answer is, since there is a loss, or at least no profit shown, and since to add depreciation would be to make a bad matter only worse, nothing is to be gained by entering into the academic discussions that inevitably follow the opening of a subject concerning which opinions reasonably may differ as widely as on this much disputed particular.

But power may be purchased, as is often suggested by those with power for sale, hence it is proper to determine at what rate this power may be purchased and come out even as compared with operation by steam-generated power. Obviously any rate less than this will be profitable.

With purchased power, the total investment will be diminished

by the costs of 20 miles of transmission line and of the generating station, it being assumed that power will be delivered at some one point on the right-of-way, whereas local conditions located the steam station 20 miles off the right-of-way (see Appendix B).

The net first cost was		$5,707,700
Transmission line, Appendix C	$120,000	
Generating station " B	1,760,000	1,880,000
Leaving a net investment with power purchased		$3,827,700

ANNUAL OPERATING COSTS
(Power purchased)

		Steam	Electric
Substation labor and supplies,	Appendix A		$59,700
Transmission and contact systems maintenance,	" C		35,576
Maintenance of way as affected by locomotives,	" H	$126,890	83,285
Locomotive repairs,	" I	270,990	70,701
Loco. enginemen, (passenger),	" J	48,300	29,100
Fuel,	" K	240,852	
		$687,032	$278,362
Bond interest at 4½ per cent			172,247
Totals		$687,032	$450,609

The difference, $236,423, should be decreased by $191,385, (the approximate tax and depreciation rate of 5 per cent on the net investment of $3,827,700), and there is left the wholly inadequate sum of $45,038 with which to purchase 53,000,000 kw-hr. at a load factor of about 20 per cent; with no profit to show for an investment of nearly $4,000,000.

For the sake of the argument let the depreciation be neglected and let it be considered that $236,423 are available for the purchase of power under the operating conditions of the service. At any time there may be four passenger and four freight trains pulling up hill simultaneously, taking a total of 32,720 kw. alternating-current input to the line. This is not the maximum number of trains that is on the mountain regularly, but represents only those taking power. A slight derangement of schedules, or an extra freight movement, citrus fruits or oil, or a blockade, for example, will cause congestion beyond any possibility of estimating. This traffic must be handled as circumstances require. It cannot be spaced conveniently for power demands, as many engineers and power men have suggested, but the term-

inal yards must be cleared as the cars accumulate. Is there any power company in the west coast country, or even beyond the reach of such a natural power source as Niagara, that would care to undertake such a load for any such yearly return as that named in this paragraph? It would net about 4½ mills; a rate that neither the purchaser nor the seller could afford to consider.

In the face of the foregoing it is difficult to see how any recommendation in favor of electrification can be made, if the opinion is based on the direct financial profit to be realized; in other words, this case is merely another example of the fact often noted, that in the great majority of cases the profits from electrification must be realized indirectly rather than directly,—increased track capacity, postponing second- or double-tracking, or the like.

It may be urged that a larger district would make a better showing. In this connection it may be noted that the line from Bakersfield to Summit is almost identical with half of the line assumed in Mr. Hobart's paper on *2400-Volt Railway Electrification.** On each side of the summit Mr. Hobart's assumed line is 3800 ft. rise in 48 miles with the ruling grade of 2.2 per cent, while the west slope of the Tehachapi is 49½ miles, rise of 3764 ft. and a ruling grade of 2.4 per cent. Also Mr. Hobart assumes freight train weight on heavy days of 1800 tons as against 2000 tons on the Tehachapi. Furthermore, the Sierra study covered a district more than double the length of the Tehachapi, and the result was the same.

In the various appendices will be found complete details of all the elements of the investigation, as noted by the cross references given after the various items of the tabulations herein.

Acknowledgments are hereby made to Mr. G. W. Welsh and Mr. F. E. Geibel, both assistant engineers in the electrical engineer's office, Southern Pacific Company, for assistance in the preparation of this paper. The former made a thoroughly painstaking study of the problem as a whole, and to the latter is due the novel method of determination of substation spacing and capacity as detailed in Appendix A.

APPENDIX A

SUBSTATIONS

Substation Spacing and Heating Loads. It is not the purpose here to go into a theoretical discussion of the economical spacing

*See A. I. E. E. PROCEEDINGS, May, 1913, p. 1012.

of substations, balancing off the losses and fixed charges of the distributing system against the losses and fixed and operating charges of the substations. Any such discussion requires the lengthy consideration of various operating conditions which seldom, if ever, are obtained in practise; hence the determination leads nowhere.

The following is simply a brief description of a very convenient and quick method of determining the feeder and substation lay-out in preliminary studies of the electrification of mounting divisions of steam railroads. The method was developed by Mr. F. E. Geibel, assistant engineer, Southern Pacific Company, in the original study of the problem.

The conditions, as set forth in the general study, require an average train speed over the electrified section. It is therefore necessary to maintain an average voltage over the sections between substations. Formulas for the average volts drop over the section were deduced as follows:

Let L = distance in miles between substations.
I = current per train in amperes.
R = resistance of distributing system in ohms per mile of circuit.
A = distance in miles between first and second trains.
B = distance in miles between second and third trains.
V = volts at substation.
E = instantaneous volt drop on line.
D = average volts drop over section between substations.
X = distance in miles between first train and a substation.

Considering first only one train between substations:

$\left(\frac{L - X}{L}\right) I$ = current drawn from one substation.

XR = total resistance to same substation.

Therefore $E = \frac{R I}{L} (XL - X^2)$

$$\text{but } D = \frac{\sum_0^L E}{L} = \frac{RI}{L^2}\int_0^L (X L - X^2)\, dX$$

$$= \frac{1}{6} R I L = \text{average volts drop.}$$

Similarly, formulas for two and three trains in a section were deduced, for average drop as follows:

One train between substations, $D = \frac{1}{6} R I L$

Two trains " " $D = \frac{1}{6} R I \left(2L - \frac{3A^2}{L}\right)$

Three " " " $D = \frac{1}{6} R I \left[3L - \frac{2(2A + B)^2}{L}\right]$

If the trains are following at equal distances then $A = B$ and the last formula becomes .

$$D = \frac{1}{6} R I \left[3L - \frac{2(3A)^2}{L}\right]$$

The loads on the substations were plotted graphically for several substation spacings up to twenty-five miles, and the heating loads were computed for each spacing. It was found, however, that the heating load varied approximately as follows:

Total heating $= 2\left(\frac{L}{A+B}\right) VI$ for trains alternately A and B miles apart, when the distance between substations is equal to or greater than the greater spacing between the trains. For trains of equal distance apart, total heating $= 2\left(\frac{L}{2A}\right) VI$. VI is the amperes per train multiplied by the substation voltage.

It is to be noted here that all of the above expressions apply only to direct-current systems and cannot be used on single-phase systems without complication. It is, also, to be noted that the formulas are deduced assuming trains running in one direction only, as, on the grades considered, the trains coming down grade do not draw a running current but only a small current for control purposes.

In applying the formulas to the problem in hand the following assumptions were made:

2000-ton trains with four 100-ton locomotives per train.

Trains 15 miles per hour, spaced alternately 5 and 10 miles apart.

Locomotive efficiency 90 per cent. Train resistance 6 lb. per ton.

Substation voltage 2400. Train voltage 2100 average.

In Fig. 2 will be found curves showing the total conductivity, in terms of total million circular mils of copper equally divided between positive and negative circuits, required to give the average voltage over the section for various grades. These curves were plotted from the formulas given above. With substation spacings up to 8.65 miles, the average drop is greater with one

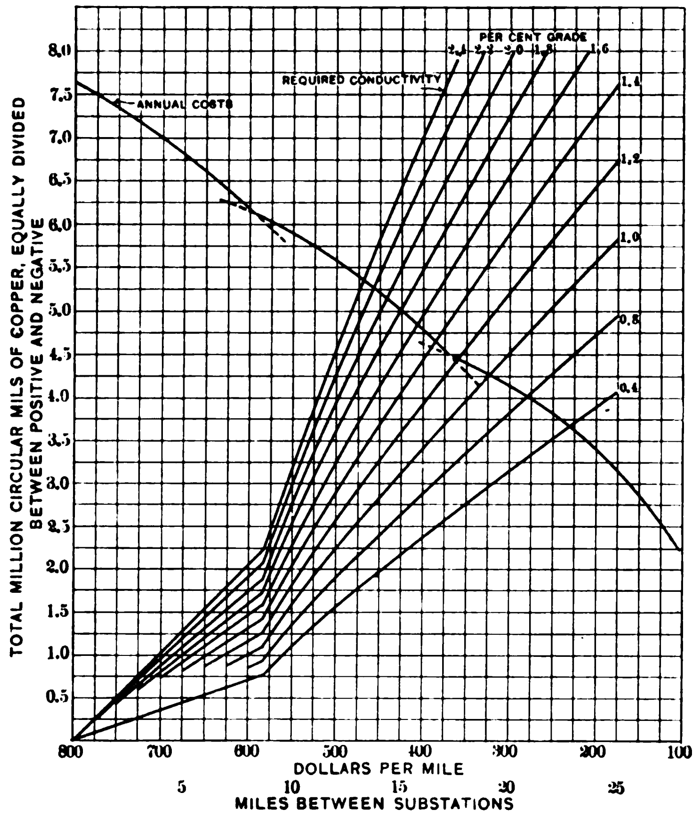


FIG. 2—CONTACT SYSTEM

train in the section, and between 8.65 miles and 26.9 miles the average drop is greater with two trains in the section. Hence the break in the curves at 8.65 miles.

There is also plotted in Fig. 2 a curve giving the annual costs per mile on a contact system of the required conductivity. A contact rail system was considered with no positive feeders but 75-lb. old rail as negative feeder. The annual cost curve

shows three distinct sections, namely: the lower section, no negative feeder; the middle section, one 75-lb. rail negative feeder; and the upper section, two 75-lb. rail negative feeders. As worked out, however, the system required no negative feeder. From Fig. 2, it is seen that the annual cost per mile on the con-

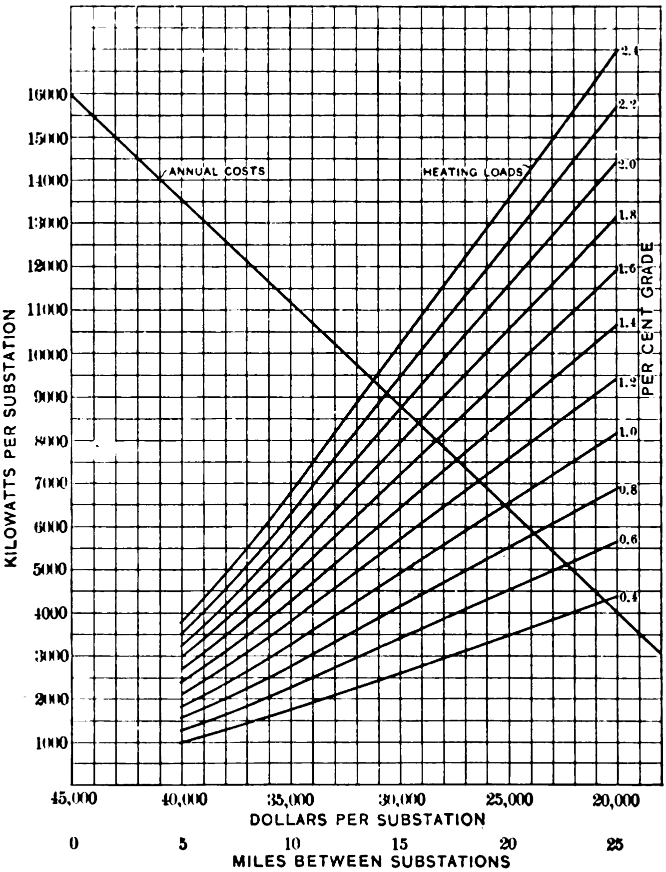


FIG. 3—SUBSTATIONS

tact system for any given substation spacing and grade can be read directly.

Similarly from Fig. 3 the heating loads on substations for any given spacing and grade may be read off, or, if referred to the annual cost curve, the annual cost per substation is given. This

latter value divided by the spacing gives the substation annual costs per mile.

The above annual costs were taken at various substation spacings on several given grades and the results, the total annual costs per mile, were plotted in Fig. 4. This gives a series of

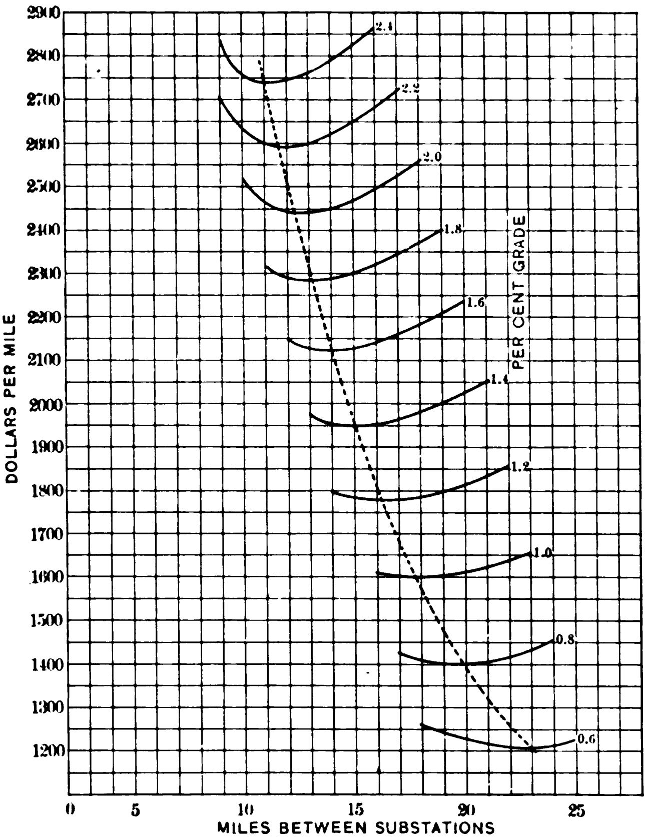


FIG. 4—TOTAL ANNUAL COSTS

curves, the minimum of each being the economical substation spacing on the given grade. These results were transferred to Fig. 5 which shows, for any given grade, the economical spacing, the heating load on substation and the size of contact rail required.

As stated in the report, the track district under study was divided into several sections of average grades. By applying

the latter curve, therefore, to these sections the spacing and heating loads of the substations are easily determined.

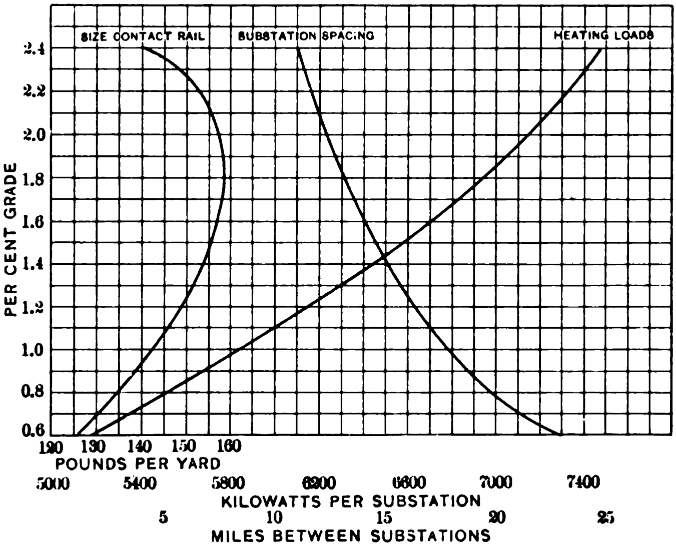


FIG. 5—ECONOMICAL SUBSTATION SPACING

After making the proper allowance for yard switching and stub ends, the following substations were located:

No. substation	Spacing	Heating load	Installed capacity
1	5 miles from Bakersfield	4900 kw.	three 2000-kw. units
2	13.5 mi.	6500 "	four 2000 " "
3	11.6 "	7200 "	four 2000 " "
4	10.5 "	7000 "	four 2000 " "
5	10.5 "	6600 "	four 2000 " "
6	13 "	6900 "	four 2000 " "
	3.7 mi. to Mojave		

The larger part of the grade being either 2.4 per cent or under 1 per cent, a 140-lb. contact rail was required for the main line and 75-lb. for sidings.

The unit first costs used are as follows:

SUBSTATION

$35 per installed kw.

The above is based on a recent west coast installation corrected for 2400-volt apparatus.

MAIN LINE CONTACT RAIL, 2400 VOLTS

Material:

110 tons special 140-lb. contact rail at $33.00 per ton..		$3630.00
Freight thereon at $13.50 per ton....................		1485.00
176 pairs splice plates delivered.............	$88.00	
Bolts and nuts..........................	12.00	
704 bonds at 74c..........................	521.00	
480 insulators, brackets and felt delivered....	480.00	
Paint..................................	20.00	
10 inclines at $7.50.......................	75.00	
5 jumpers at $100.00.....................	500.00	
Anchoring, modified ins. caps, extra 10c x 176.	17.60	
Substation connections....................	35.00	
960 long ties excess cost at 50c.............	480.00	
960 brackets for protection at 50c...........	480.00	
Lumber for protection.....................	500.00	
Bolts, screws and fittings..................	80.00	
	$3288.60	
Extras 5 per cent......................	164.40	
	$3453.00	
Store charges 6 per cent.................	207.00	$3660.00

Labor:

Delivering rail 110 tons at $1.50............	$165.00	
Installing insulators 480 at $.10............	48.00	
" protection brackets at $.10.......	96.00	
" rail.............................	200.00	
" bonds at $.30 ea.................	211.20	
" protection......................	400.00	
Painting................................	100.00	
Work train..............................	100.00	
	$1320.20	
Extras 10 per cent......................	132.00	$1452.20
		$10,227.20

Say $10,225.00 per mile

SIDING CONTACT RAIL COSTS, 2400 VOLTS

Material:

59 tons special 75-lb. contact rail at $46.50 del.........		$2740.00
352 bonds at 60c..........................	$211.20	
Other material...........................	2560.80	
	$2772.00	
Extras 5 per cent......................	138.60	
	$2910.60	
Store charges 6 per cent.................	174.60	$3085.20

Labor:

Delivery of rail 59 tons at $1.50	$93.50	
Installing bonds at 30c	105.60	
" insulators	48.00	
" protection brackets	96.00	
" rail	100.00	
" protection	400.00	
Painting	100.00	
Work train	100.00	
	$1043.10	
Extras 10 per cent	104.30	$1147.40
		$6972.60
Say		$7000.00

The above is based on Pennsylvania R.R. type of third rail with protection installed on both sides. Cost of rail is based on New York Central cost of special rail plus freight charges. Cost of specialties is taken from quotations. Labor is according to west coast practise.

Main Line Bonding

Two 10-in., 450,000-cir. mil bonds per joint.

Bonds	$570.00	
Cross bonds	75.00	
Labor	375.00	
	$1020.00	
Extras	102.00	$1122.00

Sidings and Yard Track Bonding

Two 4/0 bonds per joint.

Bonds	$320.00	
Cross bonds	100.00	
Labor	400.00	
	$820.00	
Extras 10 per cent	80.00	$900.00

The above is based on the actual cost of bonding in an installation recently made in the vicinity of San Francisco. The fact that the track would be bonded under heavy traffic should not be overlooked.

TOTAL FIRST COSTS

Substation and Distribution

Substation		
46,000 kw. at $35		$1,610,000
Contact rail		
65.84 mi. main line at $10,225	$673,000	
21.60 mi. sidings at $7000	152,000	
		825,000
Bonding		
65.84 mi. main line at $1120	$73,800	
21.60 mi. sidings at $900	19,440	
32.29 mi. yard tracks at $900	29,060	122,300
		$2,557,300

Annual Costs

For the reason that one organization should maintain all transmission and distribution system, the annual costs of maintenance and repair for contact system are to be found under Transmission Line Costs, Appendix C.

APPENDIX B

Generating Station

Two principal considerations fixed the generating station at a distance from the track: fuel and water.

Twenty miles off the right-of-way from a point 6 miles east of Bakersfield is located a large oil field from which the company obtains much of the fuel oil used in its locomotives. Plenty of water for condensing purposes is obtainable near by. The annual charges on a transmission line under these conditions do not impose so heavy a burden on the operating costs as would the delivery of oil at the right-of-way; besides, to develop sufficient water along the track would cost a great deal. For these reasons the generating station was located in the oil fields on fairly level land where excavating costs were reasonable and on soil sufficiently firm for ordinary foundations.

The load curve, Fig. 6, indicates that a three-unit station is desirable, two units of which would carry the load ordinarily, with one as a spare. A study of the load curve and train diagram fixed the maximum capacity of the units at 18,000 kw. at the two-hour overload rating—an economical size in first cost and in annual operating costs. The point of maximum economy without auxiliary nozzles is in the neighborhood of 10,000 kw., and the hand-operated nozzle will enable the machine to carry

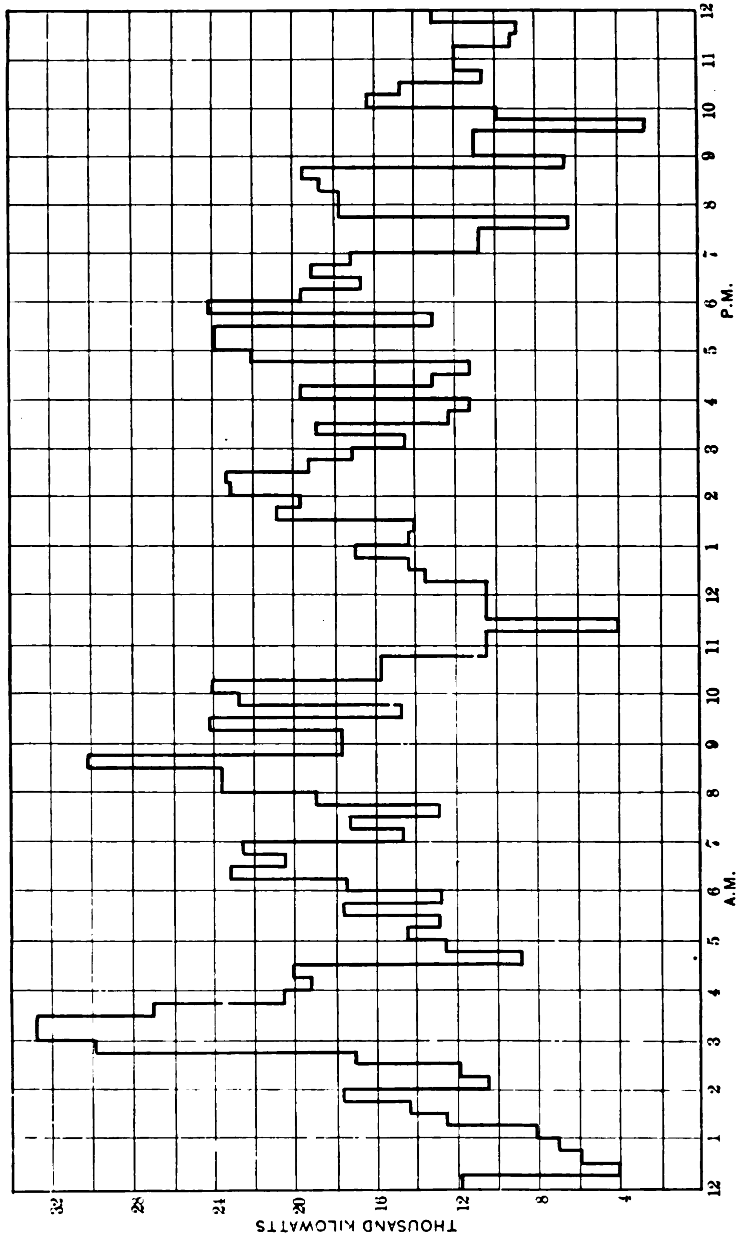


FIG. 6—LOAD DIAGRAM

between 13,000 and 14,000 kw. at the same water rate, with a by-pass for the higher overloads.

The segregated estimated prices are as follows:

Three turbines, 18,000 kw. maximum, for two hours	$400,000
Exciters and battery	25,000
Three condensers and drives	65,000
15,000 h.p. boilers, superheaters, stacks, breeching, brick-work, etc.	330,000
Pipe, valves, fittings, covering	75,000
Oil fuel sets, fire, oil unloading, house and boiler feed pumps, heaters	30,000
40,000 bbl. oil storage, blow-off, hot well, house tank, etc.	16,000
Crane	12,500
Switchboard and wiring	150,000
Step-up transformers	100,000
Condenser tunnel system	75,000
Superintendence, engineering, drawings, general labor, traveling expense, telegraph and telephone, testing plant, tools, insurance	75,000
Buildings, foundations and excavation	350,000
Incidentals	56,500
	$1,760,000

The very high temperatures in the summer months at the power house location, (which means hot circulating water), require very large condensers.

The station operating force as taken from the average practise in this part of the country is as follows:—

POWER STATION OPERATING COSTS

Labor:

Superintendent of power		$4,000
Steam:		
1 Chief engineer at	$225 per mo.	2,700
3 Watch engineers at	125 " "	4,500
3 Turbine operators at	95 " "	3,420
6 Water tenders at	95 " "	6,840
6 Firemen at	95 " "	6,840
6 Oilers at	85 " "	6,120
3 Wipers at	75 " "	2,700
1 Boiler repairer	120 " "	1,440
1 Boiler cleaner at	85 " "	1,020
1 Machinist at	110 " "	1,320
1 Machinist helper at	90 " "	1,080
1 Clerk at	90 " "	1,080

Electric:

3 Load dispatchers at	125	"	"	....	4,500
1 Chief operator at	150	"	"	....	1,800
3 Switchboard operators at	110	"	"	....	3,960
3 Asst. " "	90	"	"	....	3,240
3 Dynamo tenders at	80	"	"	....	2,880
3 Dynamo cleaners at	75	"	"	....	2,700
2 Meter testers at	110	"	"	....	2,640
Total power station, labor					$64,780
Repairs, supplies, etc					20,000
Total per year					$84,780

APPENDIX C

Transmission Line

For the distribution of power along the right-of-way to the different substations there will be required 50.5 miles of No. O twin circuit line, with an addition of 20 miles of the same line from the right-of-way to the generating station, making a total of 70.5 miles of transmission line required. The detail costs following are taken from the actual book costs of a similar transmission line installed recently under practically identical conditions.

Twin Circuit Transmission Line Costs—60,000 Volts
(Assume 3 special and 7 standard towers per mile with suspension insulators, 1 ground wire.)

Material:

3 special towers 3650 lb. each at 5½c delv'd..	$600.00	
7 standard " 3200 " " " 4½ "	938.00	
	$1538.00	
Store charges, one per cent..............	15.38	$1553.38
126 disk type insulators at $2.20............	$277.20	
108 strain " " " 1.95...........	210.60	
42 sets hdw. for suspension insulators at $1.20	50.40	
36 sets hdw. for suspension insulators at 1.40	50.40	
1 mi. 7/16 in. high strength ground wire, 1900 lb. at $3.25 cwt............................	61.75	
6 mi. No. 0 copper, 10,122 lb. at 22½c..	2277.45	
	$2927.80	
Store charges 6 per cent.................	175.67	$3103.47
		$4656.85
5 per cent for extras, etc.................		232.85
		$4889.70

Labor:

Blasting and foundations for towers—average	$60.00		
Distribution of steel	2.50		
Assembling	20.00		
Attaching insulators	3.00		
Erecting towers	10.00		
Ten towers per mile	$95.50	$955	
Distributing six cond. and one ground wire		9	
Stringing six cond. and one ground wire		125	
		$1089	
10 per cent for extras and changes		109	$1198.00
			$6087.70

OVERHEAD CONSTRUCTION

Bakersfield and Mojave Terminals and Kern Yards.

Material:

420 40-ft. tubular steel poles at $65		$27,300.00
50 34-ft. tubular steel poles at $40		2,000.00
380 35-ft. wood poles at $7		2,660.00
85 single brackets for wood poles at $4	$340.00	
40 double brackets for wood poles at $7	280.00	
2260 porcelain strain insulators at 26c	587.50	
1235 wood strain insulators at 60c	741.00	
73,500 ft. 7/16 in. high strength steel strand at $2.60 per C	1,911.00	
5500 ft. 5/16-in. iron strand at $1.25 per C.	68.75	
205,400 ft. 4/0 trolley wire at $1.30 per M.	26,710.00	
1800 trolley clamps at 75c	1,350.00	
100 center trolley supports at 80c	80.00	
1800 suspension insulators at 70c	1,260.00	
	$33,328.25	
Store charges 5 per cent	1,666.50	34,994.75
		$66,954.75
Extra material 5 per cent approx		3,225.25
		$70,180.00
8 anchor bridges (erected)		24,000.00
19,100 ft., 1,500,000-cir. mil copper feeder (erected)		21,729.50
		$115,909.50

Labor:

Erection 420 40-ft. steel poles at $35....	$14,700.00	
" 50 34-ft. steel poles at $25.....	1,250.00	
" 380 35-ft. wood poles at $8.50.	3,230.00	
" 425 cross spans at $7.50, $15, and $20..................	7,600.00	
" trolley.....	8.240.00	
	$35,020.00	
2 per cent use of tools...............	700.30	
	$35,720.30	
10 per cent contingencies.............	3,573.20	39,293.50
Total....................................		$155,203.00
Called....................................		$155,250.00

The foregoing costs are taken, (except as to insulators), from the book costs of a recent installation.

The method of construction is to span as many tracks as are necessary, without throwing track, to use steel poles at the ends of the span wires and to carry the trolley wires from a secondary span wire without the use of catenary construction.

Annual Costs

The total annual costs for maintenance of transmission and contact systems, based on the costs of similar work in other places, are as follows:—

Overhead and Contact Rail

Supt. of power distribution at $175 per mo.	
Clerk at $75 per month.................................	$3,000.00
50.5 miles high-tension transmission at $50...........	2,525.00
32.5 miles overhead construction at $250............	8,125.00
65.84 miles main line contact-rail at $150.............	9,876.00
21.60 miles sidings contact-rail at $100...............	2 160.00
67.34 miles main line bonding at 10 per cent..........	7,548.00
48.99 miles sidings bonding at 5 per cent.............	2,342.00
	$35,576.00
20 miles additional transmission at $50.............	1,000.00
	$36,576.00

In the foregoing, the estimate for bonding is based on the life of the rail in the track under consideration, it being considered that when the rail is replaced the bonds will come out and will have only a scrap value, being replaced then by new bonds.

APPENDIX D

Block Signals

At the present time the entire district between Mojave and Bakersfield is protected with automatic block signals of the usual continuous-current track circuit battery type. In case of electrification a great part of this apparatus will have to be replaced with alternating-current track circuit apparatus, because the use of track circuits with propulsion current in the rails requires selective apparatus to prevent false indications. The estimate of the signal department for making these changes is $175,000.00

APPENDIX E

Electric Shops and Inspection Shed

For the reason that the company has important division shops located already at Bakersfield, a large item for repair shops is not necessary, it being understood that the heavy electric locomotive repairs would be done in the steam locomotive repair shops. An inspection shed with pits, however, is necessary, for which the lump item of $10,000 was included, this being in the ratio of cost of the track facilities required here to the cost of similar track facilities in a shop recently erected by this company.

Note. The maintenance cost of inspection shed and tools therein is carried under the heading of " Locomotive Repairs "—(see Appendix I).

APPENDIX F

Electric Locomotives

An analysis of the train sheets covering the period of maximum tonnage over the mountain shows that there will be required 47 freight locomotives, and 11 passenger locomotives, which includes a reasonably large allowance, namely, 8 freight and 3 passenger locomotives, for repair and shopping purposes. The locomotives required for this service are so closely similar in characteristics to those upon which quotations were asked recently from the electrical manufacturers that new quotations were not requested for the purposes of this estimate, particularly since the locomotives actually quoted on were for the same operating voltages, etc., as are contemplated herein.

The unit costs were: passenger locomotives $40,000, and freight locomotives $35,000, making a total of $2,085,000 for 47 freight and 11 passenger locomotives.

APPENDIX G

Steam Locomotive Credits

It seems pertinent here to note the very significant fact that while steam locomotives are strictly interchangeable and can be moved from division to division as the necessity for varying motive power capacity develops, by reason of crop movements, or otherwise, the electric locomotives are limited in their field of operation strictly to electrified track, and as far as interchange between divisions is concerned they might as well be of some gage other than standard. An inspection of the records of the operating department shows that during a period of heavy traffic over the mountain there were in actual service 13 passenger, 47 consolidated and 13 Mallet locomotives, which, if taken at the same valuation as was used in a recent report on the Sierra-Nevada electrification, would represent an investment of $1,220,750, to which should be added at least 20 per cent for extras, shopping, repairs, etc., making the total investment in steam locomotives properly chargeable to this district = $1,464,900. It may be thought that the allowance of 20 per cent for shopping, etc., is not large enough; that the records of the steam motive power department will show a greater percentage of locomotives assigned to a given district and actually out of service; but it should be remembered that in case of sudden demands, steam locomotives are moved from division to division as stated above, and therefore it is not reasonable to charge to this district the total amount of steam motive power that would be required if the district is considered as an isolated entity in operation, as would be the case under electric operation.

APPENDIX H

Maintenance of Way as Affected by Locomotives

Many years' experience in the analysis of track maintenance accounts has shown that, independent of all other considerations, track maintenance as affected by rolling stock can be divided into two heads, locomotives and cars, the segregated costs of which have been determined very accurately. Reduced to dollars and cents, the auditor's accounts show that locomotives of approximately the same weight and run at the same speeds as those contemplated in this report, caused maintenance of way expense at a certain rate per locomotive mile, from which has been deduced the item, $83,285, given in the statement of Annual Operating

Costs. That for steam operation, $126,890, is taken from the records.

APPENDIX I

Locomotive Repairs

The figure given under this item for steam operation is taken directly from the records. The estimated cost of electric locomotive repairs, 4 cents per locomotive mile, is based on our analysis of the best data available for such costs. As to this value, opinions reasonably may differ, but it probably will be recognized that the figure named gives a rather favorable consideration to the use of electric locomotives, since the repair accounts of some of the larger railroads operating the large stelectric locomotives in this country show repair costs materially more than 4 cents, all things considered.

APPENDIX J

Enginemen's Wages

In the report it was mentioned that certain items, such as freight enginemen's wages, would not be changed materially by a change in the nature of the motive power. The reason is that the present tendency is toward the operation of large Mallet locomotives, at an advanced rate per 100 miles paid their enginemen. Since the capacity of an electric locomotive unit is essentially the same as the largest Mallet it is felt that the wages paid will have to be the same as for present freight service. The passenger enginemen's wages under electric operation are based on the same wages per locomotive mile as under steam operation, but since the electrics would make unnecessary the use of helpers on the mountain, the total has been reduced by the amount now paid helper enginemen.

APPENDIX K

Fuel

The item $240,852 for fuel under steam operation is taken from the records. It represents the oil issued to the steam locomotives and charged to them at the division cost of oil, which in turn is the cost at the wells, plus transportation charges to the particular division, with a percentage added for store expense and handling.

On the other hand, the item $100,530 for fuel under electric operation, represents the number of barrels of oil estimated to

be consumed in the generating station, at the cost per barrel of oil at the wells plus a small handling charge.

The reasons for locating the generating station at the wells are given in detail in Appendix B. The net result is that the oil costs materially less in the steam generating station than when delivered to the locomotives of the San Joaquin division.

The basis upon which the oil consumption is calculated is as follows:

PHYSICAL CHARACTERISTICS OF TRACK

	West slope	East slope
Distance (feet)	261,300	96,624
Total ascent—east	3,687	5
" " —west	77	1,280
" " —east and west	3,764	1,285
Total curvature	7,944 deg.	765 deg.
Ave. grade per cent	1.44	1.33
" curvature	3 deg.	0.79 deg.

TRAIN RESISTANCE, POUNDS PER TON

	West slope	East slope
Grade	28.8	26.6
Curvature	2.7	0.7
Friction	6.0	6.0
Total	37.5	33.3

Energy, foot-tons per ton of train lifted to Summit:

$$\text{West slope } \frac{37.5 \times 261{,}300}{2000} = 4900 \text{ ft-tons}$$

$$\text{East slope } \frac{33.3 \times 96{,}624}{2000} = 1607 \text{ ft-tons}$$

TONNAGE CONSIDERED

Passenger:

One	250-ton train each way plus 150-ton locomotive....	400 tons
One	350 " " " " " 150 " " ..	500 "
Three	400 " " " " " 150 " " ..	1650 "
Two	600 " " " " " 150 " " ..	1500 "
	Total per day each way	4050 "

Freight:	Eastbound	Westbound
Gross tons per year (trailing)...........	4,798,056	3,167,301
Number of 500 -ton units...............	9,598	6,335
Number of locomotives(minimum)......	9,598	6,335
Add 10 per cent for underloaded locomotives...........................	960	633
Total locomotives.................	10,558	6,968
Summary:		
Gross tons per year trailing............	4,798,056	3,167,301
Locomotives at 100 tons...............	1,055,800	696,800
Total tons per year..................	5,853,856	3,864,101
" " " day....................	16,040	10,600

Fuel Consumption

Passenger: 4050 tons east and west per day.

East 4050 × 4900.......	19,845,000 ft-tons	
West 4050 × 1607......	6,508,350 "	
	26,353,350 "	
Add 10 per cent for slow movements and starts.....	2,635,335 "	
		28,988,685 ft-tons

Freight:

16,040 tons east per day
10,600 " west " "

East 16,040 × 4900.....	78,596,000 ft-tons	
West 10,600 × 1607.....	17,034,200 "	
Total................	95,630,200 "	
Add 10 per cent for slow movements and starts...	9,563,020 "	
		105,193,220 ft-tons
Total passenger and freight energy per day...		134,181,905 ft-tons

$$\text{H.p-hr. per day } \frac{134,181,905 \times 2000}{33,000 \times 60} = 135,537$$

Based on previous detailed studies of similar problems we are safe in assuming 70 per cent efficiency from power station to locomotive wheels = 144,600 kw-hr. per day at the power station
= 52,779,00 " " year " " " "

Requiring, at 210 kw-hr. per bbl. of oil, 251,330 bbl.

Costing, at $0.40 per bbl., $100,530.

NOTE. The 70 per cent average efficiency given above is deduced from the following average all-day efficiencies of the plant as designed:

Transmission line..........	98 per cent
Conversion apparatus......	90 per cent
Contact system............	87½ per cent
(This being the ratio of the average volts—2100, to the generated volts—2400).	
Locomotives..............	90 per cent

making a net efficiency of 69½ per cent, which for practical purposes has been called 70 per cent.

Since the position of all trains on the track is known with great accuracy from the train dispatcher's sheets, it is expected that substations on which there is no load will be shut down completely until the train dispatcher advises the station operator that a load is approaching his substation. The foregoing accounts for what may be considered a high average conversion efficiency.

NOTE. In order to show how closely to the average the tonnage runs from month to month, the table of tonnages for the fiscal year 1911-12, is given in Appendix L2.

Fig. 7 gives the train diagram for the conditions of traffic under which this estimate is made. It shows only those trains that are running up-hill, no account being taken of the down-hill trains for obvious reasons. Of course this is not strictly accurate because the trains will consume some small energy in supplying air for brakes, etc., and in occasional movements into and out of sidings, but the error in estimating the probable down-hill use easily may be greater than the total energy consumption of the down-hill trains.

From the foregoing train diagram is made the load diagram given in Fig. 6, the method being as follows—As has been stated

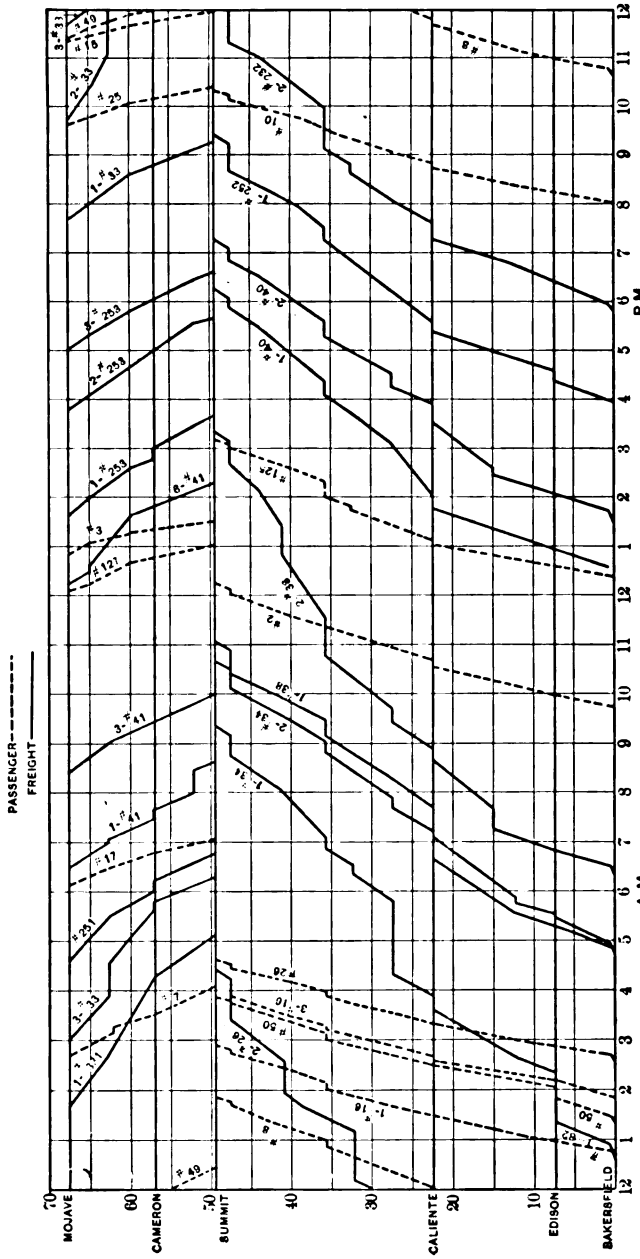


FIG. 7—TRAIN DIAGRAM

previously, in determining the load diagrams from the train diagrams, certain close approximations were made as regards ruling grades, curves, and average grades. Obviously, if a load diagram were made from the actual track plans and engineer's profiles, the time and labor consumed would be very great and out of all proportion to the accuracy of the results; in other words, it is believed that with close approximation to actual conditions the results are within the probable error of the more extended operation.

The individual loads for each particular train on the various approximated grades were taken from characteristic curves of locomotives assumed to be used. These individual loads were then plotted against time, and combined train by train to give the load diagram as shown. The average speed of trains was assumed at approximately 30 miles per hour for passenger trains and 15 miles per hour for freight trains. The ordinates representing power used are plotted at 15-minute intervals. The integrated area of the load diagram as shown will not check with the average energy consumption as given in Appendix K, for the reason that the load diagram is intended to represent maximum travel conditions, it being a step in the determination of the generating station capacity and load factor. In this connection it is interesting to note that the load factor of this diagram is practically 50 per cent when determined on the ½-hour basis. Other students of this problem and writers on this subject seem to have deduced their opinions as to load factors from a selected curve, somewhat similar to this. It should be reasonably evident to anyone who thinks on this subject that the load factor one is concerned with here is the yearly load factor and not the daily. Taken on the basis of the maximum hour and the average year, the load factor of this installation would be close to 20 per cent.

For the information of those who are not familiar with the actual track conditions on the Tehachapi Mountain, the condensed profile is given in Fig. 1; also the tunnel characteristics are given in Appendix L1.

APPENDIX L1

Tunnel Clearances, etc.

Tunnel No.	Length	Height	Curvature	Lining material
1/2	539.5	17ft.to18½ft.	10 deg.	Timber
1	245.8		10 "	"
2	232.2		10 "	"
3	707.7		0	"
4	256.3		10 deg. 05 min.	"
5	1145.9		0	"
6	303.7		10 " 10 "	"
7	532.7		10 "	Rock
8	690		0	Timber
9	426.2		0 " 20 "	"
10	306.6		10 "	"
11	158.8			Rock
12	756.3		10 "	Timber
13	513.8		10 "	"
14	512.7		10 " 04 "	"
15	360.7			"
16	262.5		10 "	"
17	260.9		10 "	"
	8212 ft. =	1.56 mi.		

60 per cent (approx.) of total length is on 10-deg. curve.

APPENDIX L2

Tonnage, July 1, 1911 to June 30, 1912.

July, 1911	564,201
August, 1911	638,665
September, 1911	640,178
October, 1911	666,807
November, 1911	671,708
December, 1911	683,618
January, 1912	688,883
February, 1912	701,846
March, 1912	694,475
April, 1912	666,762
May, 1912	712,251
June, 1912	635,963
Total	7,965,357
Average month	663,780

	Tons	Per cent of average
Minimum month	564,201	85.05
Maximum "	712,251	107.2

THE GULF OF GEORGIA SUBMARINE TELEPHONE CABLE

BY

E. P. LA BELLE and L. P. CRIM

Presented under the auspices of the

Papers Committee for the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

1817

THE GULF OF GEORGIA SUBMARINE TELEPHONE CABLE

BY E. P. LA BELLE AND L. P. CRIM

Abstract of Paper

The paper describes the submarine telephone cable recently laid between Point Grey and Nanaimo, on Vancouver Island, 52.5 km. in length. It is continuously loaded, being the first cable of this type in use in America. The construction of the cable is described and illustrated and also the method of laying it. A careful study was made of the relative advantages of a continuously loaded and a coil-loaded cable for the conditions obtaining in this case, and the results have amply justified the selection of the continuously loaded type.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., September 9-11, 1913.

THE GULF OF GEORGIA SUBMARINE TELEPHONE CABLE

BY E. P. LA BELLE AND L. P. CRIM

The recent laying of a continuously loaded submarine telephone cable, across the Gulf of Georgia, between Point Grey, near Vancouver, and Nanaimo, on Vancouver Island, in British Columbia, is of interest as it is the only cable of its type in use outside of Europe.

The purpose of this cable was to provide such telephonic facilities to Vancouver Island that the speaking range could be extended from any point on the Island to Vancouver, and other principal towns on the mainland in the territory served by the British Columbia Telephone Company.

The only means of telephonic communication between Vancouver and Victoria, prior to the laying of this cable, was through a submarine cable between Bellingham and Victoria, laid in 1904. This cable was non-loaded, of the four-core type, with gutta-percha insulation, and to the writer's best knowledge, is the only cable of this type in use in North America. This cable is in five pieces crossing the various channels between Bellingham and Victoria. A total of 14.2 nautical miles (16.37 miles, 26.3 km.) of this cable is in use. The conductors are stranded and weigh 180 lb. per nautical mile (44.3 kg. per km.). By means of a circuit which could be provided through this cable by way of Bellingham, a fairly satisfactory service was maintained between Vancouver and Victoria, the circuit equating to about 26 miles (41.8 km.) of standard cable. All communications to points on Vancouver Island north of Victoria were routed through this cable circuit. As a consequence the speaking range from Vancouver to the Island was limited to a few points near Victoria,

and Nanaimo was the extreme limit of commercial service, and conversation was not attempted except under the most favorable conditions. Under some conditions conversation was possible except for the distorting effect of the unloaded cable.

By using the new cable, Nanaimo is made the center of distribution for Vancouver Island. The longest line that will ever be connected at Nanaimo will extend to the north end of Vancouver Island, and will be about 250 miles (400 km.) in length, so it can readily be seen that satisfactory service may be established to any point on Vancouver Island through the new

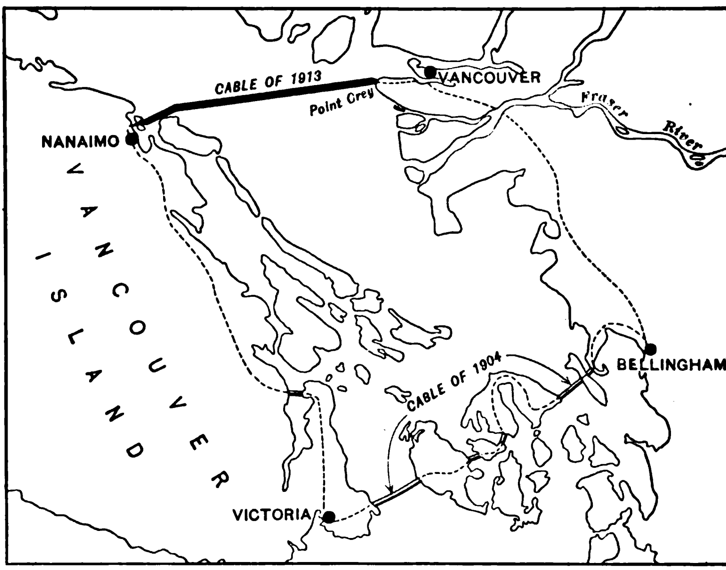


FIG. 1.—ROUTE OF CABLES OF 1904 AND 1913. BROKEN LINES INDICATE AERIAL LAND LINES.

cable. It was with the idea in mind of using Nanaimo as the distributing center that the existing route was chosen for laying the cable.

It is quite important to the long life of a submarine cable that a rock bottom and exposure to tidal currents be avoided as much as possible. It is also quite essential that the shore ends be landed in mud or sand and that they be kept buried, at least as far as the low water line. It is believed that the route chosen will prove to be very satisfactory.

The new cable was manufactured by the Henley Telegraph Works, in England, and has the following mechanical properties:

Conductors. Four conductors, each consisting of a central wire, surrounded by twelve wires of annealed copper, having a total weight of 300 lb. per nautical mile (73.4 kg. per km.); total diameter of conductor 0.1385 in. (3.518 mm.).

Loading. One soft iron wire 0.012 in. (0.305 mm.) in diameter, wound round the conductor and having seventy turns per inch (27.6 turns per cm.).

Dielectric. Three coats of best gutta-percha alternating with three coats of Chatterton's compound. Total weight of dielectric per nautical mile 300 lb. (73.4 kg. per km.). Diameter over gutta-percha 0.409 in. (1.04 cm.).

Cabling. Four cores laid around a yarn center, wormed, brass taped and served with yarn.

Armoring. Fifteen galvanized steel wires each 0.192 in. (0.487 cm.) in diameter, separately tarred and served with tarred yarn.

Outer Serving. Two coats of tarred yarn, and two coats of preservative compound.

Diameter. Diameter of completed cable 1.956 in. (4.97 cm.).

Weight. Weight of completed cable, eight English tons per nautical mile (4.38 metric tons per km.).

The same type of armoring was used throughout, and on account of the armor wires each being served with tarred jute, the completed cable was very flexible.

The cable has the following electrical qualities, as measured on 31.3 nautical miles (58 km.) of the completed cable in the factory at a temperature of 75 deg. fahr. (24 deg. cent.). All quantities per nautical mile.

	Conductor resistance	Electrostatic capacity	Dielectric resistance*
	Ohms	Microfarad	Megohms
No. 1 Core	4.004	0.3449	258
No. 2 Core	4.004	0.3455	256
No. 3 Core	4.004	0.3449	268
No 4 Core	4.005	0.3449	274

*After one minute's electrification.

PER NAUTICAL MILE OF LOOPED CIRCUIT

	Cores	Conductor resistance	Electrostatic capacity
		Ohms	Microfarad
Circuit A	1 and 3	8.008	0.1724
Circuit B	2 and 4	8.009	0.1726
Superimposed or phantom circuit on A and B		4.0045	0.3450

The following values were obtained by an eminent independent testing authority on a length of one-twentieth of a nautical mile cut from the completed cable. Results are per nautical mile, and tests were made with sinusoidal current at a frequency of 800 cycles per second, at a temperature of 56 deg. fahr. (13 deg. cent.).

Column A, loop or side circuit cores 1 and 3
" B, " " " " " 2 and 4
" C, superimposed or phantom circuit.

	A	B	C	
Effective resistance R	9.16	9.14	4.69	ohms
Effective inductance L	11.56	11.54	5.45	millihenrys
Effective capacity K	0.1647	0.1662	0.3338	microfarad
Effective leakance S	12.24	11.26	19.84	microhms
Ratio S/K	74.3	67.8	59.4	
Attenuation constant	0.01892	0.01874	0.01966	

The following results were obtained in the laboratory of the manufacturers on the completed length of 31 nautical miles (58.5 km.) coiled up in the iron tank and covered with water, using sinusoidal current at 800 cycles per second, as before.

Circuit	A	B	
Open impedance Z_o	349.35	337.4	Vector ohms
	\32°31′	\33°54′	angle
Closed impedance Z_c	185.75	187.5	Vector ohms
	/23°53′	/24°43′	angle
Characteristic impedance Z	254.5	251.4	Vector ohms
	\4°19′	\4°56′	angle
Attenuation constant	0.01946	0.01940	

After laying, the cable was tested for dielectric resistance, for capacity, and for conductor resistance. The transmission equivalent was measured in terms of standard cable and tests were made for crosstalks.

SUMMARY OF TESTS AFTER LAYING

	Conductor resistance	Mutual capacity
	Ohms	Microfarad
No. 1 Circuit	8.008	0.175
No. 2 Circuit	8.008	0.174

	Electrostatic capacity	Dielectric resistance
	Microfarad	Megohms
No. 1 Core	0.347	445
No. 2 Core	0.349	451
No. 3 Core	0.351	461
No. 4 Core	0.347	461

The above results are per nautical mile. Dielectric resistance is corrected to 75 deg. fahr. (24 deg. cent.).

The actual length of cable in use is 28.3 nautical miles (52.5 km.) and its mean temperature was 49.6 deg. fahr. (9.8 deg. cent.) at the time the measurements were taken. Speech tests showed a standard cable equivalent of eight miles with zero loop on each end, and 5.75 miles, with 12 miles of standard cable at each end to reduce reflection losses.

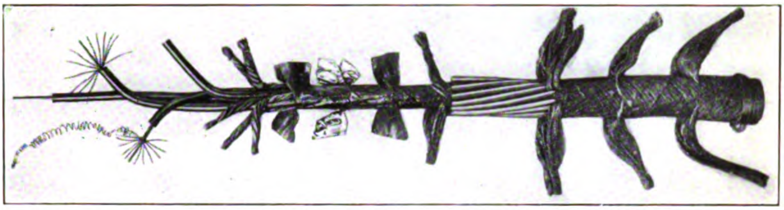
The finished cable was shipped from England to Vancouver on the ship *Crown of Galicia*. It was stored in a steel tank while on shipboard and kept under water. The temperature was observed daily throughout the voyage. Upon arrival at Vancouver, it was transferred from the tank in the hold of the *Crown of Galicia* to the hold of the barge *Princess Louise*, from which it was later laid. The actual operation of laying was begun at the Point Grey end at 4 a.m. June 16th, and finished at Kanaka Bay on New Castle Island at 7:30 the evening of the same day. The illustrations herewith show the laying operations in detail. Throughout the entire operation of laying, one pair was under continuous test for insulation resistance, while the other pair was being utilized for communication with the shore. As a matter of precaution the two pairs were interchanged at intervals so that no fault in the dielectric could escape observation for any length of time. While the cable was being laid, conversations were carried on with parties in Vancouver, Victoria, Seattle and Portland. Two tugs were used to tow the cable ship, which was without power of its own. Telephonic communication was maintained with the tugs by means of rubber covered wires strung on the hawser. Observations to determine the location were taken at regular intervals with a sector, and a log of operations was carefully kept. The tension on the cable was observed by means of a dynamometer, and the amount of cable paid out was read from the rolometer attached to the paying-out drums. With the exception of a light rain in the morning, the weather was excellent, and a number of guests observed the laying operations, which were without accident.

A cable hut is provided at each of the shore ends for housing the protective apparatus and making the connections between the cable and the aerial land lines. The protective apparatus is of the Lodge-Muirhead type, and consists of three reactive coils with four discharge points, located around a central brass disk, which is grounded to the armor wires of the cable. Each of the cable cores is laid through a protector of this type, and a fuse is inserted between the protector and the line wire, and also between the protector and the cable. All of the protective apparatus is housed in a waterproof cast iron case.

The two physical circuits provided in this cable were satisfactory in every way and are each equivalent to about 5.75 miles of standard cable. The phantom circuit, however, is not so satisfactory. It is only fair to the manufacturers, however, to state that a satisfactory phantom circuit was not guaranteed. It will be seen that the capacity and leakance of the phantom circuit is just two times as great as in the physical circuits, while the resistance and inductance are about one-half each. This causes the attenuation constant of the phantom to be somewhat greater than that of the physical circuits. There is also some crosstalk between the physical circuits and the phantom, being equivalent to about 75 miles (120 km.) of standard cable. Tests for this determination were made with local battery sets in the cable huts connected directly to the ends of the cable. This crosstalk is undoubtedly caused by inductive unbalance in the cable. On account of the salt water penetrating to the outside core of the gutta-percha, the wires are shielded from each other electrically. Any disturbance that is transmitted from one wire to another must therefore be of an electromagnetic nature. The capacity of the cores in this type of cable depends upon the thickness of the dielectric, and in every case is the capacity from the wire to the ground (salt water), as the sea water penetrates the cable to the gutta-percha. Efforts to decrease the capacity of this type of cable by a paper wrapping under the gutta-percha, in order to increase economically the diameter, have failed because of the moisture content of the gutta-percha being absorbed by the paper.

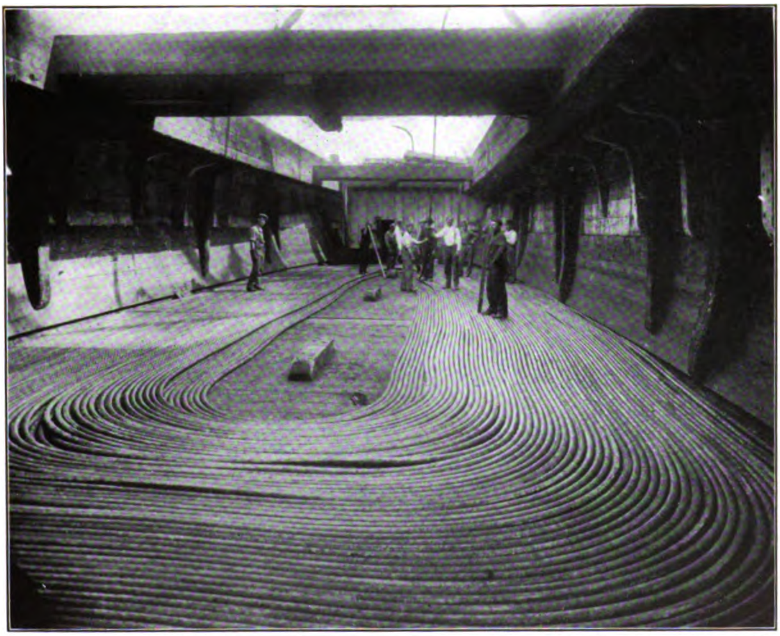
The uniformity of the capacity then depends upon the cores being exactly of the same dimensions and located symmetrically. It can readily be seen that a slight eccentricity of conductor in the dielectric will change the capacity accordingly.

The inductance of these cable circuits is artificially increased



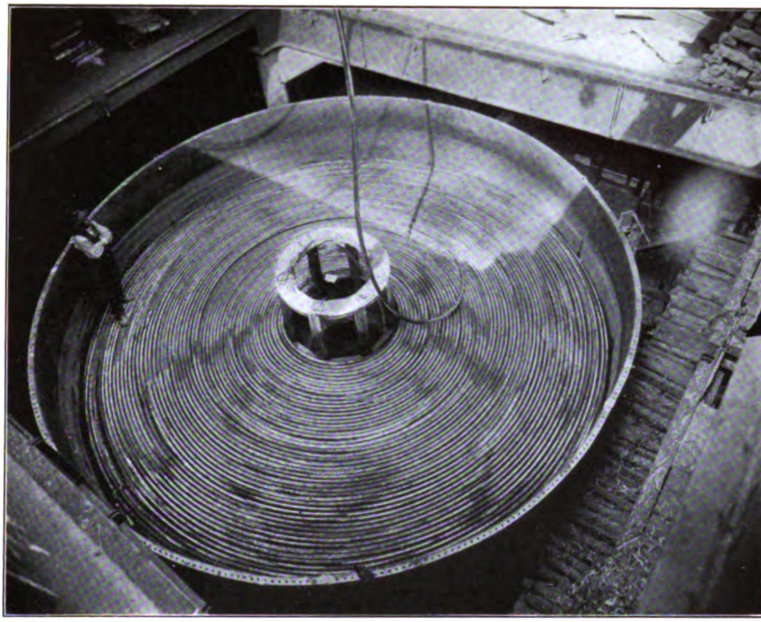
[LA BELLE AND CRIM]

FIG. 2.—DETAILS OF CABLE CONSTRUCTION.



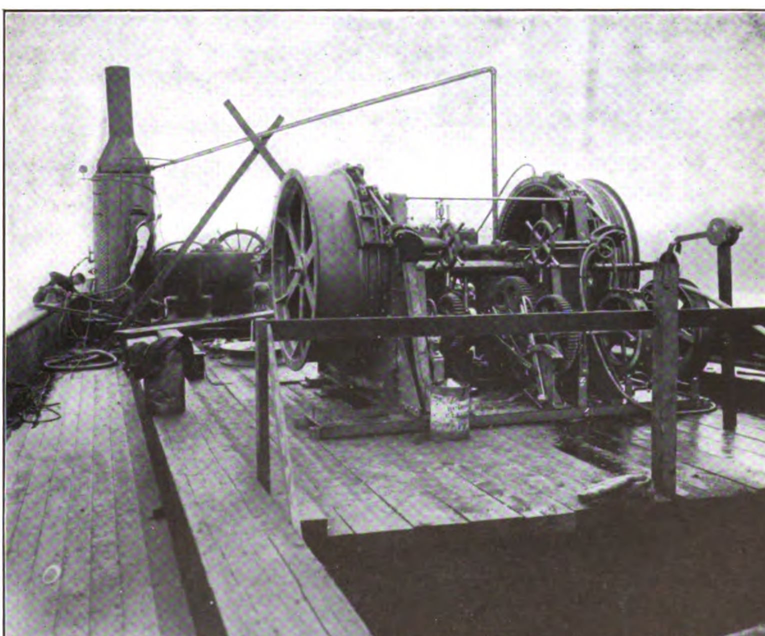
[LA BELLE AND CRIM]

FIG. 3.—COILING OF CABLE IN HOLD OF *Princess Louise*.



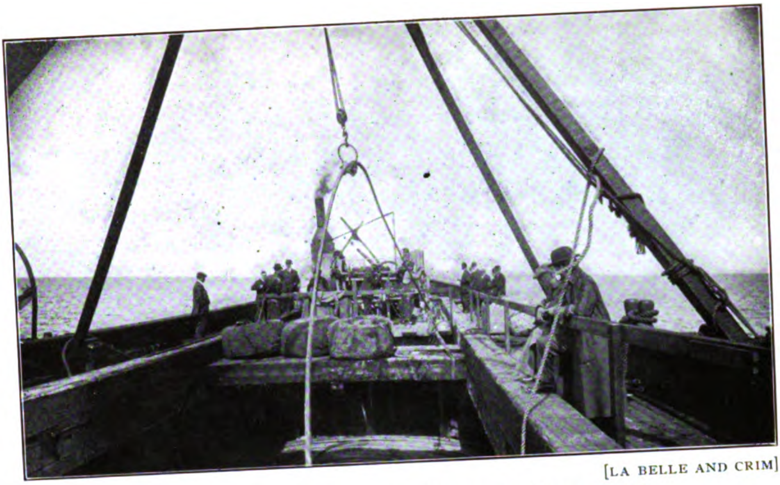
[LA BELLE AND CRIM]

FIG 4.—CABLE IN TANK ON BOARD *Crown of Galicia.*



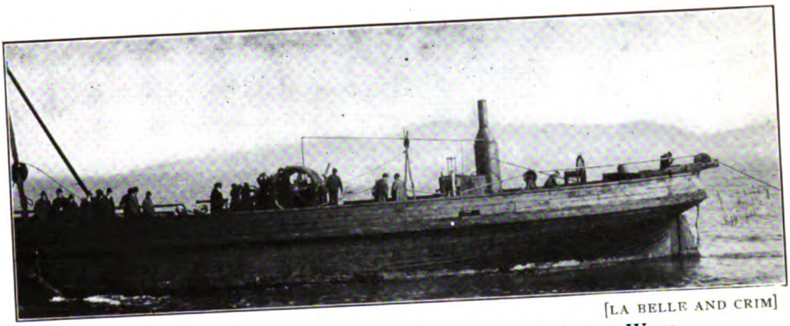
[LA BELLE AND CRIM]

FIG. 5.—PAYING-OUT DRUMS.



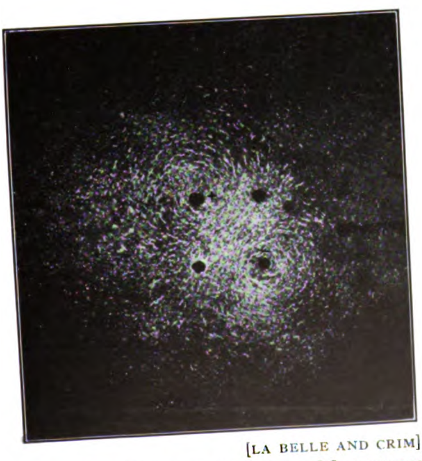
[LA BELLE AND CRIM]

FIG. 6.—CABLE LAYING GEAR IN OPERATION.



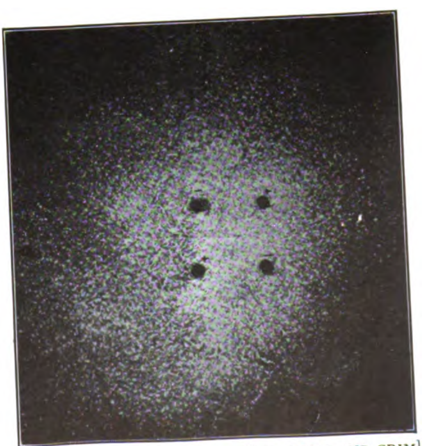
[LA BELLE AND CRIM]

FIG. 7.—SIDE VIEW OF CABLE SHIP UNDER WAY



[LA BELLE AND CRIM]

FIG. 8.—DISTRIBUTION OF MAGNETIC FLUX IN FOUR-CORE CABLE, CURRENT FLOWING IN PHYSICAL CIRCUIT ONLY.



[LA BELLE AND CRIM]

FIG. 9.—DISTRIBUTION OF MAGNETIC FLUX IN FOUR-CORE CABLE, CURRENT FLOWING IN PHANTOM CIRCUIT.

by a winding of soft iron wire around the copper conductor, which increases the permeability of its magnetic field. This is the well-known Krarup system of continuous loading. The permeability of this wire may be affected in three ways, namely, aging, by straining it beyond its elastic limit, and by permanently magnetizing it. Aging occurs in nearly all iron used in magnetic circuits and the magnitude of the change of permeability varies with the different pieces of iron. It is thus possible that the inductance of the different cores of a Krarup cable might be thrown out of balance by the iron wires aging differently. It is known that the permeability of magnetic iron is affected by straining it beyond its elastic limit. When it is considered that the loading wire is only 0.012 in. (0.305 mm.) in diameter, and that in order to hold it around the copper conductor so that it will remain evenly distributed, it is necessary to apply it with considerable tension, it is more than likely that a considerable amount of this wire has been heavily strained. This is indicated by its appearance. During manufacture the different sections of core were spliced together in such a way as to neutralize as far as possible any unbalances that could be detected at that time. It will be seen that the total capacities and inductances of the different cores are in a fair degree of balance. There is very little danger of the iron wrapping used in continuous loading ever becoming permanently magnetized, as this would require a very heavy current.

It is customary to measure the direct-current insulation resistance of a gutta-percha core at 75 deg. fahr. (24 deg. cent.) and after one minute's electrification. The insulation resistance increases quite rapidly after the initial electrification and only reaches a fairly constant state after some time. This effect, although not well understood, seems to be somewhat similar to the polarization effect of an electrolytic couple. The dielectric resistance so obtained cannot be used to deduce the leakance S for calculating the attenuation constant and circuit impedance. Measurements for this quantity must be made at telephonic frequencies and voltage, and owing to the extremely small quantity of power involved, are exceedingly difficult to make with any degree of precision.

Gutta-percha is rarely employed as an insulator for telephone conductors, with the exception of submarine cables in deep water. While information regarding its various characteristics is not very plentiful, a brief statement of its qualities may be of interest.

It is composed of pure gutta, rosin and water. It is a vegetable gum secured from certain tropical trees very much the same as India rubber. It is collected by native labor, and shipped in the raw state to the factory where it is prepared for commercial use. The first step in its preparation is to remove all impurities, as far as possible, which is done by boiling in water. It is then put through a masticating machine, after which it is rolled out into thin sheets.

The wire which is to be insulated with gutta-percha is first given a coat of Chatterton's compound, and then a coat of gutta-percha is applied with a sheathing machine, in much the same manner as lead sheaths are applied to the ordinary paper-insulated telephone cable. Additional layers are applied alternating with layers of Chatterton's compound, until the required thickness of dielectric has been obtained. It should be noted that gutta-percha is not subjected to any process similar to the vulcanization of rubber, but is used in the raw state. It contains no sulphur, and copper wires do not require tinning before being insulated with gutta-percha.

In general, rosin does not increase the initial insulation resistance of gutta-percha, but if it is present in too great proportions it tends to separate, especially upon exposure to heat and light, and causes cracks to form in the insulation. Ordinary grades contain from five to six per cent moisture. The insulation resistance increases very rapidly with a decrease in temperature, so that at 45 deg. fahr. (7.2 deg. cent.) its insulation resistance is about ten times that at 75 deg. fahr. (24 deg. cent.). If it is heated much above 80 deg. fahr. (27 deg. cent.) it soon softens, and in a completed cable this would allow the cores to become deformed, especially if the cable were subjected to any considerable pressure, such as the lower coils in a cable tank. Instances have been known where the copper conductor by its own weight became so eccentric in the core that a large quantity of the cable was ruined on account of the insulation becoming too thin.

Generally speaking if different grades of gutta-percha are mixed together, a higher dielectric resistance is obtained, but the fibrous structure is not so good as if one quality were used throughout.

The splicing of a gutta-percha-insulated conductor is one requiring no little skill and care. It is necessary in splicing a four-core cable that the spliced conductors be of equal length, so that no one splice will be subjected to more than normal

stress. In splicing the conductors, the ends are scarfed and soldered together. Then the joint is given a close wrapping of fine copper wire, which is also soldered all over. A second wrapping of fine copper wire is then applied in reverse direction and soldered only at the ends. In case the joint was so strained as to break the soldering in the main conductor of the first wrapping copper wire, this last spiral wrapping would still form a metallic connection across the break. In joining the dielectric, the same number of layers of gutta-percha are applied, alternating with Chatterton's compound, as are used in the manufacture of the core. The gutta-percha is warmed with a spirit lamp until plastic, and is applied with the fingers. The finished splice must not have a much greater diameter than the unspliced core and must show leakance not in excess of a piece of core ten times the length of the splice. Owing to the inability of gutta-percha to stand exposure to moderately high temperature, light and air, it has been the practise among European engineers to splice a piece of rubber-insulated cable on to the gutta-percha below the water level at the shore ends, and thus make the landing with rubber-insulated cable. As it is well nigh impossible to make a perfect splice between rubber and gutta-percha, it is necessary to employ a water-tight junction box if this method of terminating the shore ends is used. No method has yet been found for cementing rubber and gutta-percha together so that the joint will hold for any appreciable length of time. The practise of using rubber insulation for the shore ends was not followed in laying the Point Grey-Nanaimo cable, for the above reasons. The shore ends have been buried from the terminal in the cable hut to low water, and on account of this, will not be exposed to temperature very much above that of the sea water. Sufficient slack has been left in the cable so that in case the ends at the terminals lose their insulating qualities, they may be cut off and the cable reterminated. In this way the ends of the cable may be kept in excellent condition by allowing a few feet extra for the cable reterminating.

In a four-core cable such as is generally used for telephone purposes in deep water, the two opposite cores are used to form each circuit. It is not necessary, if the cores are arranged symmetrically about the center, that the wires be twisted in pairs in order that each circuit will be unaffected by the current flowing in the other. The wires of one circuit do not inter-loop the lines of magnetic force from the other, and each of the wires

is under the influence of equal and opposite electrostatic fields. This latter is not true of a cable submerged in salt water, due to the shielding effect of the salt water. As mentioned before, it will therefore be seen that the two circuits are quite independent of each other both electromagnetically and electrostatically. The same thing is true of the superimposed or phantom circuit, but the results obtained in practise are not so good as with the two physical circuits.

In selecting a design of cable suitable for this service, the choice was practically limited to a four-core gutta-percha cable, loaded either by the continuous or Krarup system, or by the use of Pupin coils. Owing to the depth of water (1300 feet = 396 meters) a paper-insulated lead-covered cable was not seriously considered. The stress during the laying would so strain the cable in passing over the drums and sheaves that there would be great danger of impairing the insulation between the wires. Owing to the highly distortional effect of non-loaded gutta-percha cable, it was necessary to eliminate such a cable from consideration. It remained, therefore, to choose between the two types of loading. It is well known that a coil-loaded cable is quite superior to a continuously loaded cable, or in fact any other design of cable, when electrical qualities alone are considered. The continuously loaded cable is mechanically quite simple and upon its completion is equally as strong as a non-loaded cable such as has been used for telegraph service for years, even at the maximum depth of the ocean. In a coil-loaded cable the only acceptable design of coil so far employed is one which surrounds the four cores of the cable, and which is taken inside the regular cable armor. This causes an increase in the diameter of the cable from two to three times its unloaded diameter, and in spite of precautions which may be taken in the manufacture, these loaded points are the weakest spots in the cable, both electrically and mechanically.

The two best known examples of coil-loaded submarine cable extend from England to France across the English Channel, and from England to Belgium. The former cable is about 20 nautical miles (37.1 km.) in length, and the latter about 40 nautical miles (74.2 km.) in length. Neither of these cables is laid in a very great depth of water, and both are under the supervision of the British Post Office, which has available cable ships especially designed for the laying and repairing of such cables. The older of these cables has only been in use about three years, and

during this time no serious case of trouble has developed, so that the actual difficulties to be encountered in repairing this type of cable can only be forecasted in view of experience in repairing the non-loaded type.

In order to keep the transmission in a coil-loaded cable at its original quality, it is necessary that the spacing of the coils be kept as originally laid out, allowing only a variation of five per cent. It is quite obvious that this is not true of the continuously loaded type, and any increase in the length would cause an increase in the transmission loss, only in proportion to the increased length of the cable employed.

In case of a fault in deep water, the cable is picked up by means of a grapnel and as soon as it is brought to the surface it must be cut in order to relieve the great strain. One end is retained in the grapnel and a line is made fast to the other end which is thrown overboard and a buoy attached. The end which is retained is tested for the fault, and unless the fault is in the cable which was thrown overboard, the cable is picked up until the fault is located and repaired. It is then necessary to splice in a piece of new cable and pay out until the abandoned end is picked up, when as much slack as possible is taken out and the two ends spliced together. It will thus be seen that a considerable additional length of cable will be introduced in case of a fault in very deep water. In case such a repair was made at a depth of 1300 ft. (396 m.), under the most favorable conditions, it is quite probable that 800 to 1000 ft. (244 to 305 m.) of additional cable would be introduced. As 300 ft. (91 m.) is the greatest allowable variation with coils spaced one nautical mile (1.854 km.) apart, it will be seen that the coil spacing would be badly disarranged and serious reflection losses introduced. It must also be remembered that no gutta-percha cable is manufactured in America and the only submarine loading coils so far manufactured have been made in Europe, and in case expensive repairs were necessitated, it might be necessary to secure special equipment and skilled labor from Europe, while with the type adopted, repairs can be made with the equipment and labor commonly used in repairing telegraph cables.

Comparisons between the two types of loading have been made and much discussed by different authorities, and a comparatively recent paper on this subject by Mr. J. G. Hill summarizes arguments in favor of the two types in a very excellent manner. It is a well known fact that the two types of cable having the same

transmission efficiency may be produced, the coil-loaded cable at much less expense than the continuously loaded cable. Mr. Hill bases his comparison on two factors; one, that inductance can be added by the continuous method of loading only up to a certain limit, say 20 millihenrys, while by coil-loading, any desired amount of inductance may be added to the circuit; and second, that the ratio R/L, obtainable with the coil-loaded cable, is much less than that obtained in continuous loading. The limit of economic loading depends upon the amount of resistance added to the circuit in increasing its inductance.

The attenuation constant of a cable is unfavorably affected by the addition of resistance. All known methods of increasing the inductance of a circuit, also increase the effective ohmic resistance, and Mr. Hill compares the efficiency of the added inductance in terms of the amount of resistance so added. It has been found that the ratio between the added resistance and the added inductance for continuous loading is about 110, while a good design of loading coil has a ratio of R/L of about 60. These ratios are true only for the amount of inductance used in ordinary practise. The increase in effective resistance, as is well known, is due to the eddy currents and hysteresis losses in the iron of the magnetic circuit. Eddy current losses can be reduced by subdividing the iron. Hysteresis losses depend upon the degree of saturation of the magnetic field, which is kept low in all telephone circuits. Pupin coils employ a toroidal magnetic core composed of a large number of turns of very fine iron wire with some type of enamel insulation. It is possible to employ several layers of fine wire on a continuously loaded cable, and several have been laid which use three layers. The improvement in the magnetic circuit by such subdividing is not so marked as in the coils, and the expense is very much greater. It would seem that future design will show a still greater advantage in the coil-loaded type of cable, as it is probable that the R/L for loading coils can be reduced still more, economically. It might be of theoretical interest to remark that as the effective resistance of a coil-loaded conductor is a function of the frequency, it is therefore impossible to build a distortionless circuit employing iron magnetic fields.

We can therefore summarize the arguments that we considered in selecting the type of cable as follows:

Arguments in Favor of a Coil-Loaded Cable. 1. Could employ smaller conductors, and less gutta-percha, and secure a cheaper

cable for the same transmission equivalent (disregarding terminal losses).

2. Could give the phantom circuit the same degree of loading as the physical circuits.

3. Could add any desired amount of inductance.

4. Aging of the iron cores of the loading coils could not unbalance the circuits.

Arguments in Favor of a Continuously Loaded Cable. 1. Simplicity of construction.

2. Could be laid and repaired like an ordinary gutta-percha insulated telegraph cable.

3. Short lengths added in repairs do not materially affect the transmission.

4. Not liable to faults at loading coils.

5. Faults could be located more accurately by means of resistance measurements.

6. Is not heavily loaded, and therefore has less reflection losses at shore ends where it joins to non-loaded open wire lines, than would be the case with a coil-loaded cable.

7. Known to be reliable at the greatest depths of water.

It was after due consideration of the above factors that the continuously loaded type was decided upon, and the results obtained have amply justified the selection.

MIDWINTER CONVENTION PAPERS

GROUP I. HEATING, HEAT MEASUREMENTS, RATING BY HEAT

(a) MOVING MACHINERY

Notes on Internal Heating of Stator Coils, by R. B. Williamson.

Measurement of Temperature on Rotating Electric Machines, by L. W. Chubb, E. I. Chute, and O. W. A. Oetting.

Method of Determining Temperature of A-C. Generators and Motors and Room Temperature, by H. G. Reist and T. S. Eden.

Thermocouples and Resistance Coils for the Determination of Local Temperatures in Electrical Machines, by J. A. Capp and L. T. Robinson.

(b) TRANSFORMERS

Methods of Determining Temperature of Transformers and of Cooling Medium, by S. E. Johannesen and G. W. Wade.

Methods of Measuring Temperature of Transformers, by C. Fortescue and W. M. McConahey.

Correction of Transformer Temperature for Variation of Room Temperature, taking into Account both Copper and Iron Losses, by C. Fortescue.

(c) TEMPERATURE CORRECTION

The Temperature Rise of Stationary Induction Apparatus, by J J. Frank and W. O. Dwyer.

Effect of Room Temperature on Temperature Rise of Motors and Generators, by M. W. Day and R. A. Beekman.

Effect of Air Temperature, Barometric Pressure and Humidity on the Temperature Rise of Electrical Apparatus, by C. E. Skinner, L. W. Chubb and Phillips Thomas.

A Laboratory Investigation of Temperature Rise as a Function of Atmospheric Conditions, by C. B. Blanchard and C. T. Anderson.

Laws of Heat Transmission in Electrical Machinery, by Irving Langmuir.

(d) CABLE HEATING

Current Rating of Electric Cables, by R. W. Atkinson and H. W. Fisher.

The Heating of Cables Carrying Current, by S. Dushman.

DISCUSSION ON GROUP I PAPERS (HEATING, HEAT MEASUREMENTS, RATING BY HEAT) NEW YORK, FEBRUARY 26, 1913. (SEE PROCEEDINGS FOR FEBRUARY, 1913.)

(*Subject to final revision for the Transactions.*)

Comfort A. Adams: There is one question I would like to ask of Mr. Dushman, concerning Mr. Langmuir's paper. When Mr. Langmuir first published his work on Convection, I happened to be interested in the subject, and put the material into such shape that I could use it easily, but as the theory was only checked by tests on very small wires, I am in doubt as to the validity of the method when applied to large wires or to plane surfaces. I should like to know how far it is safe to go in this direction.

S. Dushman: For a plane surface the thickness of the film is about 0.4 cm., and that will hold practically down to 500,000 cir. mils cable. Below that, the thickness of the film varies with the diameter of the cable, and a table is given.

Comfort A. Adams: Is that the same information as given in the paper which was published in the *Physical Review?*

S. Dushman: I do not think so.

William F. Dawson: I would ask Mr. Dushman and Dr. Langmuir if they have investigated the specific heats of the various insulating materials. We have many data in respect to the thermal resistivity, but glancing through the papers I see no mention of the specific heat of the insulating materials. The specific heat of the various metals is fairly well known, but we do not seem to have available the specific heat of the insulating materials, and that certainly is very important in determining the rapidity with which various conductors will increase in temperature.

I have made some investigations in respect to crane motor ratings, and found that, roughly, the thermal capacity could be assumed at some three to four times the thermal capacity of the copper, but, of course, that is entirely empirical and probably not very accurate. I believe it was Mr. E. H. Rayner who made the investigation at the National Physical Laboratory in 1905 for the English Standards Committee who made the broad statement that the specific heat of insulation material was six times that of copper, but I imagine that is only an approximation.

Leo Schuler: When the International Electrotechnical Commission held its meeting in Zurich in January, the experiments made in this country with regard to the influence of room temperature on the heating of electrical machinery were brought to our attention by your American representative, Mr. Mailloux, who is here present. At that time Mr. Mailloux was under the impression that the influence of air temperature would be very much higher than has been represented in the papers. As we understood from Mr. Mailloux, your experiments have shown that a machine would be heated at a lower temperature so much more than at a higher temperature that the final temperature

attained by a machine would be practically the same, within certain limits, whether the air temperature is high or low.

C. O. Mailloux: That is what I said.

Leo Schuler: Between the limits of 25 deg. cent. and 35 deg. cent. air temperature, the final temperature would be practically the same. However, as far as I can see now, this is certainly not the case. If it had been the case, it would certainly be quite revolutionary compared with the former ideas we had on that subject.

The members of the Committee in Zurich were also of the opinion that it would be quite revolutionary, and that therefore we should drop all discussion on the subject of air temperature. Now, I must say that this is the most important question which I thought would be discussed here, and I should like to have some further information from the gentlemen who made the investigations in regard to the practical results they think their investigations will have on the Standardization Rules which are now to be adopted.

As far as I have seen from the papers, it is advised to leave a correction for air temperature out of the Standardization Rules, and simply stick to the present practise, at least to our present German practise, and simply add the air temperature to the rise and do nothing else.

There is another question: In the paper by Mr. Skinner allusion is made to the "fog-laden air," but there is not much said about that subject. Am I to understand that experiments have been made with fog-laden air and that the cooling of fog-laden air is much higher than ordinary air; and if this is the case, is there any prospect of a practical application of this method? One would think, of course, that the fog-laden air would very soon destroy the insulation by exposing it to the moisture, but I have seen a report in a German paper that in America experiments are being made to use fog-laden air for the more effective cooling of electrical machinery. Perhaps you will give me some information on that.

M. W. Day: With regard to the total temperature obtained under different room temperatures, the question was raised at one time whether possibly in a cold room the motor would rise to a point nearly as hot as in a hot room, but that is far from being the case. The fact that we wished to bring out was, that in a great majority of these cases the temperature rise in a hot room was less than it was in a cold room, but not enough less to make the total temperature the same. Take the case which is shown in Fig. 7, where one machine is run at 47 deg. cent. and the other at 24.5 deg. cent., the temperature at the commutating spool has 20 deg. rise in the hot room and 22 deg. rise in the cold room. That is a semi-enclosed motor. Now, with the open motor without fan shown in Fig. 4, in one or two cases the reverse of this rule holds true, but, take for instance, the shunt field by thermometer; in one test it shows 32 deg. and in

other tests about 33.5 deg., a very small difference, but still enough to be considered when we come very close to meeting specifications.

Turning back to Fig. 1, where the motor is totally enclosed, there is a greater difference. Take the case of the armature where the room temperature was 4.5 deg., the rise of the armature was 41 deg., and where the room temperature was 25 deg., the armature rose about 35 deg. There is 6 deg. difference in temperature rise, with about 20 deg. difference in the room temperature. About the last of the year we sent a copy of this paper to Mr. Mailloux, so that it might be considered at the meeting of the International Electrotechnical Commission in Zurich.

H. M. Hobart: I had charge at one time of some experiments in fog-laden air. The results of the investigations were valuable. I am not prepared to disclose the results but I will state my opinion that fog-laden air will afford a commercially valuable means of cooling machinery. When we have learned to take advantage of a very great number of little points, which are necessary to success, there will be a field for it.

Leo Schuler: I ask whether it is looked upon as a practical question.

H. M. Hobart: I should be disposed to recommend going much further with it, at some time when other things do not stand in the way.

C. O. Mailloux: I would like to make clear the attitude of the delegate from America to the International Electrotechnical Commission, which I do not think was made clear by my colleague, Mr. Schuler. At the time of my departure for Zurich, there were only two of the papers presented here today which were ready, namely the one by Day and Beckman and the one by Steinmetz and Lamme. These papers revealed such radical tendencies and promised revelations of such an important character that I felt it incumbent upon me to warn the Special Committee on Rating at Zurich, when it assembled to discuss the question of rating, not to go too fast in discussing the question of ambient temperature. Feeling that the Standards Committee had a great deal more ammunition up its sleeve, to use a figurative expression, I suggested that discussion might well and profitably be postponed by the International Electrotechnical Commission until after the Midwinter Convention had been held, or until after the papers which had been promised us were thoroughly discussed; but the Committee did not coincide with me. They did not seemingly believe the Americans were quite as wise as I intimated, and they were skeptical in regard to the value of the papers and their discussion. However, by way of protest, I requested the privilege of abstaining from any vote or participating in any formal action; and there was inserted in the Proceedings a note to the effect that the American delegate abstained from voting on this question, feeling that there would

soon be made public in America the results of important researches which would call for very radical modifications of the rules. That is the way the record stands today. The position I took was that any action which the Commission took at Zurich would necessarily be subject to revision and would have to undergo revision of a more or less radical character, after the results of this Convention, including the papers and the discussion, had become public.

Charles P. Steinmetz: Regarding the result, that the temperature rise at higher room temperature is less, I would say that the result is not unexpected, but is what should be expected from the radiation laws. We should expect from the radiation laws that the higher the room temperature the lower is the temperature rise at the same energy dissipation. Unexpected was the result of the single set of experiments which led to the rule previously formulated, which was introduced in the Standardization Rules away back in the last century, when the experiments were first made. The results were introduced into the rules, as they were the only evidence available at that time. Like many other things, these data were put in as the best information available, hoping that the establishment of that rule would lead investigators to study it and give us more exact information. Unfortunately, this hope was not realized until the investigations which are being published today.

W. A. Durgin: Today's discussion of permissible insulation temperatures has emphasized the importance of obtaining reliable means of getting at hot spot temperatures, and as the first group of papers is particularly concerned with such means, it seems that each should receive careful consideration. The central station company with which I am connected desires to place itself on record as being in favor of ascertaining the temperature of large unit windings by exploring coils.

These coils, according to one of the papers, are rather fragile, expensive, difficult to install and require precise measurement. Our experience is quite the reverse. First, as to fragility, we have installed a total of 120 coils in ten turbo-generators, ranging in size from 8 to 20 megawatts. Fourteen of these coils, or 12 per cent, have been damaged and the remainder have been in service from one to 4½ years, the average age of all coils being 2½ years. Some of these are installed between armature coils, some between coil and iron and some on end turns. The expense is negligible, the coils being wound of No. 30 double cotton covered wire in our own laboratory and usually consisting of a single layer some 3 feet long and 1 inch wide. The difficulty of installation will be easily met if you use the thermometer or armature resistance method of following operating temperatures as opportunity will be presented at the time of rewinding your machines. The precision of measurement required is at most merely that of a Wheatstone bridge, while there are at present on the market indicating instruments which may be permanently connected to the coils to give the operator direct temperature readings.

The value of these coils has been greater than we first expected, since they supply a ready means of following the temperature of the machine continuously, thus checking the condition of the ventilating ducts. The operating department has come to depend on our periodic heat tests for necessary information as to when to remove a field, clean the stator, and put the entire unit in first-class condition.

We appreciate, of course, that any exploring coil may not and probably will not give the hottest spot, but it does give a temperature which is strictly related to that of the conductor and this temperature is so much higher than that shown by either the mean resistance or temperature method that as yet we have not been able to get the manufacturers to admit its applicability in determining the rating of a machine.

For all these reasons, therefore, we wish to urge that in reformulating the Standardization Rules the temperature coil method be given very serious consideration, and if possible, presented in conjunction with some average temperature gradients for the various classes of insulation whereby we may determine the temperature of conductor corresponding to the temperature coil indications.

B. G. Lamme: I would like to say something in connection with what the last speaker stated. Last month I presented a paper before the Institute on the subject of Turbo Generators, and in that I called attention to the fact that, in large turbo-generators, the temperature drop from the hottest part to those parts which were accessible to measuring instruments, was often excessive; that is, there might be rises of 80 deg. in the slot and 40 deg. or 50 deg. in the end windings. That is a class of machinery in which the temperature drop is liable to be excessive and no thermometer or resistance measurement is going to give indications which are worth anything unless you know approximately the internal drops. In such apparatus thermo-couples or exploring coils give a much better approximation to the true temperatures. Such devices do not give the hottest temperatures, but they locate the hot parts and give an approximation of temperature at those points. In certain classes of machinery where internal temperature drops are liable to be very high, measuring devices of that sort are advisable.

M. E. Leeds: As the importance of the measurement of hot-spot temperatures is generally admitted and the two methods of making these measurements which seem to give the best results are by means of thermo-couples and exploring coils or resistance thermometers, it would seem worth while to consider the relative advantages of these two methods, which may be summarized as follows:

The thermocouples have the advantage of small size and convenience for insertion, low cost, and small liklihood of deterioration. They have the disadvantage that the forces available

for measurement are very small, being only thirty to fifty millivolts per degree and require unusually sensitive and relatively expensive apparatus to measure them, and that it is necessary to make a cold-end correction which is such that the scale of the indicator does not read temperatures directly.

Resistance thermometers have the advantage that the forces available for measurement are relatively large, and robust indicating apparatus having moving parts and general construction, the same as ordinary moving coil switchboard instruments with an open easily read scale, may be used; no correction of any kind is necessary and the scale of the indicator reads temperatures directly. They have the disadvantage of greater first cost when cailbrated to be direct reading and constructed so as to insure permanent reliability.

In the case of the testing laboratory of the manufacturing plant where temperatures are to be measured at a very large number of points and where laboratory assistants may be trained to use the more delicate apparatus and make the necessary corrections, it is quite possible that thermo-couples will be more economical in spite of the large expenses of the reading devices.

In the case of operators of machines where the number of points to be measured is small, the situation is a different one, and the resistance thermometer seems to have decided advantages in that the temperature may be read directly from a robust instrument like other switchboard instruments without special attention, manipulation or corrections of any kind. The higher cost of the parts that go into the machine are to a very large extent offset by the lower cost of the indicating instrument. Should the service require it, the forces available from a resistance thermometer are large enough to operate a simple form of recording instrument with a commutating device which would automatically record in succession the temperature of the various parts of the machine.

I notice a slight mistake in the paper by Chubb, Chute and Oetting, apparently due to an oversight, in the statement that the exploring coils or resistance thermometers must be calibrated for the particular length of lead with which they are furnished. This is not the case for either three- or four-lead construction. The only object in having three or four leads is to compensate for the lead wires, and this compensation is rigid, and is quite independent of the length of the leads.

In the paper by Capp and Robinson is the statement: "The practical value of resistance thermometers for high temperatures is doubtful. Base metal couples are permanently changed in resistance by continued use."

The value of this statement depends on the definition of high temperatures, which is not given. There is a very considerable amount of data now available to show that properly constructed resistance thermometers of nickel wire do not permanently change their resistance when used at temperatures under 250 deg. cent.

L. W. Chubb: In answer to Dr. Leed's criticism on the relative merits of the thermocouple and the resistance coil, let me say that the greater sensibility of the bridge method in measuring with the resistance coil does not justify its use when other errors of great magnitude and of unknown quantity may creep into the results. For instance, resistance coils, consisting of very fine nickel wire, are very easily broken, when being installed in the machine. Also if you are to use such exploring coils to measure the hot spot, you must put them where there is a magnetic field, and it is well known that the resistance of nickel is not the same in a magnetic field as it is without the field.

Recent tests with such exploring coils put in the air gap of a turbo showed 2 deg. cent. jump when the turbo was excited. This was not an inductive kick, but a change in the resistance of the coil.

The thermocouple can be put right where you want it, and quick and more accurate readings of the hot spot can be taken. There are no errors of leads and it is not subject to magnetic fields in the slot of the machine. The use of the potentiometer is advocated when using a thermocouple. Portable, self-contained instruments can be had at a reasonable price and they are sufficiently sensitive to read to a small fraction of 1 deg. cent.

L. T. Robinson: I favor a resistance thermometer over the thermocouple for very obvious reasons; it is an easier thing to handle, and I think when you tack a potentiometer on to anything it is hardly a commercial device. It is a fine thing for research work, but I do not think they would want a thing like that in a central station. I do not see anything in this nickel coil. There is no necessity for it. I see no reason why copper winding is not perfectly satisfactory. Possibly it may be true that nickel has a larger temperature coefficient, it also has a larger resistivity, and that means a coarser wire, and you can in that way build up quite an argument, but, nevertheless, the fact remains that you can make perfectly satisfactory copper coils, that all the cost that goes into them is the labor of making the coil and putting it in. The real trouble is to get the thing in where you want it, without doing some damage to the machine, and to be able to find the ends after you have it there, and it has been there a while. It is quite a problem. It is introducing one class of work, that is, instrument work, into an entirely different class of apparatus, and the people who are familiar with preparing and insulating windings, etc., have not the facility and the fingers to handle the small temperature coil, and they first have to learn how to handle it, before it will be a real commercial success.

R. F. Schuchardt: It is somewhat astonishing to hear a discussion of exploring coils made of nickel or platinum, when copper coils are so simple and successful.

In the installations Mr. Durgin referred to, where we have

90 per cent of the coils installed still in service, we made them of double cotton covered No. 30 copper wire, winding the coil non-inductively and flat with a thickness of a single conductor. We placed them between the armature coil and the wooden wedge, and in a single generator we installed a dozen or more coils in various locations, so that if we lost one or two because of broken connections we still had enough to get satisfactory readings.

There is another point in connection with the use of exploring coils, in generators particularly, which is of great importance. With such coils installed, we can easily put an indicating device on the machine which will tell us the temperature at the point of measurement, which should be as near as we are able to get it to the probable hottest part.

I would like to make this suggestion: That, while, as stated, it is not the function of the Institute to tell manufacturers how to get results, we can very properly recommend to them that, as they put an oil gage on bearings to indicate when the oil level gets below the safe limit, they ought also to attach a temperature indicating device so the operator can readily know when the safe limit of load has been reached.

Elmer I. Chute: The method suggested in Messrs. Reist and Eden's paper of artificially creating a lag in the thermometers responsible for the measurement of the room temperature, somewhat corresponding to the natural lag in the apparatus under test, has much to commend it. Constant conditions as regards surrounding air in tests on rotating apparatus are much to be desired, but are seldom attained. Under varying air conditions, especially in tests on larger machines, some such device should facilitate the obtaining of more consistent and accurate temperature rises.

The method of covering thermometers, when temperatures are to be taken while running, is without doubt the most important feature in connection with their use for this purpose. On this account, the first table given in this article should be of especial interest to all those concerned in the testing of rotating apparatus. The results here given were, in certain respects, so foreign to the experience of the present speaker based on comparative tests previously taken on various types of machines, that additional tests were undertaken to determine if possible wherein the discrepancy lay. This discrepancy consisted chiefly in results given in this table for temperatures obtained with a covering of putty for thermometers as compared with a covering of felt in the shape of a small thin pad.

Tests as outlined by the authors of this paper were made and were thoroughly confirmed, that is, the thermometers protected by the putty gave from 5 to 8 deg. in 80 higher than those covered by the felt, and checked within ½ deg. of the true temperature. The true temperature was determined from the average of a number of readings taken around the coverings by a small quick-

acting thermocouple that had been especially checked for the occasion.

It was thought that some of the discrepancy may have been due to the felt pads being affected by the excessive humidity of the surrounding air caused by the proximity of the boiling water, so the same test was repeated with electrically heated grids furnishing the required temperature. In this test at 90 deg. cent. the two methods checked within 3 deg. of each other; the one covered with the putty still giving the higher temperature.

TABLE I

Test No.	Rating of machines in kv-a.	Speed	Temperatures in deg. cent.				Part measured
			Thermometer covered with putty	Thermocouple	Thermometer covered with felt	Thermocouple	
1	150	1200	51	55.7	53	54.5	Core
2	1000	600	61	65.3	68	68.4	Core
3	1000	300	47.8	51.2	52.5	52.1	Core
4	1000	300	51	55.7	53	54.2	Core
5	1000	300	49	50	52	53	After shut down
6	125	300	38.5	39.9	38	38.2	Coil
7	580	750	45.3	49.3	50	49.9	Coil
8	580	750	51	52	50.5	49.9	Core
9	90	560	41	41	42	43	Coil
10	90	560	47	49	43.5	44	Core
11	400	120	28	29.5	32.5	31	Coil
12	400	120	31	32	33	32	Coil
13	400	120	46	46	47	47.	Core
14	400	120	47.5	47	46.5	47	Core
15	2000	600	53	54	32	30.5	Coil
16	2000	600	33	37	37	37	Coil
17	2000	600	55	58	56	57	Core
18	75	277	33.5	34.5	33.5	32.8	Coil
19	75	277	37	37	35.5	36	Coil
20	75	277	53	54.7	54	54.2	Core

Tests were next conducted on machines themselves in actual operation. These tests were quite numerous. Table No. 1 gives a few of the results obtained.

Thermometers covered with each material were placed in corresponding conditions and the true temperature obtained in each case by exploring around the covering or pad with the thermocouple previously mentioned.

The experiments so far conducted indicate that the discrepancy is chiefly due to the amount of air passing over the coverings. The heat being readily transmitted through the covering of putty enables it to be carried off rapidly while in the case of the

felt there is considerable temperature gradient through the material.

It may be stated that after shut down the temperature equalizes to some extent, although the thermometers covered with the putty seldom reach the maximum registered by those covered with the pads.

The absence of all mess and the facility with which the felt pad may be adapted to almost any location on either windings or laminations are strong points in its favor, but the obtaining of temperature closely approximating the true temperature is the vital point to be considered.

Charles P. Steinmetz: The exploring coil or thermocouple is very valuable in certain classes of machines, that is, high voltage, high power generators, while in other machines it is not applicable. The exploring coil or thermocouple has however two disadvantages: First, in those machines which have one coil per armature slot, it does not show the hottest spot, and if located between the coil and iron, it shows the temperature outside of the insulation, which may be much nearer to the iron temperature than to the copper temperature. If located between the coil and wedge, it shows a temperature the significance of which it is practicably impossible to interpret. Only where there are two coils per slot, and the exploring coil is located between the two coils, then it comes nearer to the copper temperature, but may be higher or lower. If, in addition to the results shown by the exploring coil, the heat resistivity of the insulation is known, you can calculate the copper temperature from the indication of the exploring coil and the flow of heat through the insulation provided we know the flow of heat—from the copper to the rest of the machine. This however, we do not know. We could only know this, where the entire heat energy flow transversely through the insulation. In such cases we can correctly interpret the results indicated by the exploring coil. But where a large part flows lengthwise, then the exploring coil temperature has no simple relation to the copper temperature. The exploring coil is mainly valuable, as Mr. Schuchardt pointed out, as an indicating device giving the operating engineer some notion of the temperature condition of the machine, at any moment. But it does not give us the much-desired information where the hot spot is and how hot it is.

Leo Schuler: I think it would be a great drawback if you came to the conclusion to prescribe in the Standardization Rules the adoption of a thermocouple or resistance coil, because, as Mr. Steinmetz pointed out, you will probably not be able to fix that coil at the hottest point. I might mention an experience I had some time ago on a 5000-kv-a. turbo-generator. It was prescribed by the specification that the temperature of the hottest spot should be measured. One would expect the hottest spot on such a machine to be the center of the stator coil in the middle of the machine, and we therefore put a thermo-

couple at that point. As a matter of fact, the temperature measured by that thermo-couple was 10 deg. lower than the temperature measured by the total resistance of the coil. As a matter of fact, it was a cold spot.

This was easily understood later; the end windings of the machine were heavily wrapped with insulating tape outside and the dissipation of heat was very bad there, and when measuring by a thermometer at the end windings you got a much higher temperature than at the so-called hot spots. If you really say in your new rules that the manufacturer should place a thermocouple or something of that kind on the hottest spot of the machine, then I think the manufacturer would be very wise to find out the correct place for that coil.

A. E. Kennelly: I want to say that I noticed in these papers that we are discussing that there are various inferred absolute temperatures of copper from 233.3 to 238. The most recent value given by the action of the Bureau of Standards and which, I understand is likely to be accepted by the International Electrotechnical Commission, is 234.5. That is an easy number to remember.

Another point is that the unit of thermal resistivity is given in some of the papers as watts per deg. cent. per cu. in. That is generally admitted to be inaccurate. It should be watts-inches per degree cent.; or watts per deg. cent. in a cubic inch. That is, it should multiply by the inch and not divide by the cubic inch. This is important, when transferring to metric measure.

Another point is that one of these papers brought out to us the fact that at lower room temperatures, the temperature increase is greater than at higher room temperatures, which seems at first very surprising. We are accustomed to think of the heating effect of constant current strength in a coil of copper wire at different temperatures. Here the I^2R loss increases with the room temperature and the temperature elevation may be expected to increase also with the room temperature.

With constant power input, however, or with constant impressed difference of potential, the case would be different—here we have a higher temperature reached with respect to surrounding objects, and the radiated loss increases as the fourth power of the absolute temperature. I think that explains the fact taken in conjunction with another important principle, that part of the core losses diminish as the temperature goes up. The eddy-current losses diminish as the temperature goes up, and therefore there is less loss at a higher temperature than at a lower temperature.

B. G. Lamme: I like the way the discussion is going this evening, because it is so nearly in line with the recommendations in the paper on temperature and electrical insulation. In that paper, we recommended certain temperature limits obtained by conventional methods of measurement, plus an internal drop

which cannot be measured accurately. If, in the proposed conventional methods, thermo-couples or resistance coils be included as one class of thermometer measurements, then our recommendations for determination of temperature by conventional methods of thermometer and resistance will hold for all kinds of apparatus. In those cases which were beyond the limits of the mercury or fluid thermometer the thermo-couple or resistance coil could be used instead. The method proposed remains the same, whatever the method of measurement. This morning apparently there was considerable disagreement regarding our proposed method of getting at the hot spots. This evening, it is apparently the opinion that if we use a thermo-couple or exploring coil in a high voltage armature winding, and thus obtain the nearest we can to the high temperature and make a reasonable allowance for the internal drop, the result will be what is wanted;—but that is just what we proposed this morning.

I wish to take exception to one statement made by Mr. Robinson. I would limit the use of exploring coils or thermo-couples to stationary apparatus, for in rotating apparatus experience shows that such devices are not satisfactory during operation, as some moving contact must be interposed to obtain readings when in operation. These are not very satisfactory, according to my experience. Moreover, rotating armatures represent a great proportion of the total apparatus on which temperature measurements are to be made, as this covers all direct current armatures. Therefore, the thermo-couple or exploring coil should be limited to stationary apparatus, or to moving apparatus only after shutdown.

L. T. Robinson: I am willing to accept Mr. Lamme's limitation for rotating members. It is just so.

James Burke: We have been considering various methods of determining hot spots. I would suggest one other method—the method of mind reading hot spots. In applying the mind reading method, if we find by thermometer we have 40 deg. temperature increase, and by resistance of the winding, 50 deg., then we can say by mind reading that the probable hot spot is 60 deg. If by thermometer we have 40, and by resistance 55, we may conclude that the hot spot is 70 deg.; if by the thermometer we have 40 and by resistance 60, we may conclude the hot spot is 80 deg. It is an approximate treatment of it, but perhaps comes near the true hot spot temperature. It does not tell us where the hot spot is and it does not tell the exact truth, but it approaches it.

C. P. Steinmetz: How about when the thermometer reading shows a higher temperature than the resistance method?

James Burke: Then we can conclude that the thermometer reading is the truth.

Robert Lundell: I wish to refer to the increase in temperature of machinery in hot and cold rooms. I cannot help thinking

that the machines which were tested were rather inefficient at the low loads, that is to say, I believe the losses at no load and particularly the excitation losses were unduly high. Now, if the excitation losses had been very small, the main current I^2R losses would have more than offset the decrease in watts taken by the hot field in a hotter room. It is quite clear that as the temperature runs up the shunt coils take less watts, and also that the core losses become smaller. The windage increases somewhat, consequently the radiation of the heat is better, but I believe if the machines had been designed so as to be highly efficient at low loads, this free speed current would be extremely low, and I believe the result would have been opposite to what it was. I have certain machines in which the excitation only amounts to one-third of one per cent, and I believe if I make that same test on those machines the results will be different because then the main current I^2R losses adjust the difference.

F. D. Newbury (by letter): The paper brings out a point of importance in the rating of electrical apparatus that is often overlooked, thereby leading in many cases to positions scarcely tenable. I refer to the fact that the only important temperature is the maximum temperature of parts adjacent to the insulation. There is such a large factor of safety required—representing the difference between the measured outside temperatures and the allowable inside temperatures—with our present methods of temperature measurement that the results from such measurements are of little real value in judging a machine, and their approximate nature certainly does not justify a rigid adherence to the limits set.

Mr. Williamson's paper points the way toward a more rational basis for judgment, but the assumption made that all of the heat from the copper passes through the slot insulation into the laminations may be far from correct. There are, at least, three paths in parallel for the escape of heat from the copper.

1. Through the insulation to the laminations.
2. Through the insulation and wedge to the cooling air in the air-gap.
3. Through the length of the copper to the exposed ends of of the coils.

The division of the flow between these paths follows laws analagous to the more familiar laws in electric circuits. The drop in temperature along a given path is proportional to the heat "resistance" of that path, and to the heat "current" flowing; and in parallel paths the heat current divides inversely with the complete resistances. Or, a part of one path only need be considered, in which case the flow of heat will be determined by the resistance of the partial length considered and the difference in temperature (potential) involved. It is evident that if the temperature of the tooth laminations is equal to the temperature of the copper, no heat can flow from one to the other and there will be no drop through the slot insulation. In that case all

of the copper heat will flow through the copper to be liberated at the free ends of the coils and through the insulation adjacent to the wedge. This condition is approximated locally in many turbo-generators, it being relatively easy to secure low copper temperatures and difficult to secure uniformly low core temperatures. Or, to consider the opposite extreme, the tooth temperature may be so much lower than the copper temperature that all of the copper heat will flow through the insulation to the core. This is the assumption on which the author's formulas are based, and this condition is approximated in the short-circuit test mentioned by the author, the copper loss being increased 56 per cent above normal while the core loss is negligible. This explains why the test results and calculated results check. Similar short-circuit tests were made more than a year ago on a 14,000 kv-a. generator with the following results:

SHORT-CIRCUIT TEST NORMAL CURRENT

Actual temperature of copper 52 deg.

Temperature outside of insulation against tooth laminations 34 deg.

Drop in temperature through insulation 18 deg.

Air temperature 26 deg.

The same generator was tested on open circuit and normal voltage with the following results:

Actual temperature of copper in different slots 42 deg. to 49.5 deg.

Temperature outside of insulation in contact with tooth laminations in one slot 45.5 deg.

Drop through insulation minus 3.5 deg. to plus 4 deg.

Air temperature 29 deg.

These results bring out very clearly the difference in heat flow with different distribution of losses.

In the tests referred to by Messrs. Chubb, Chute and Oetting (Fig. 2,) the effect of varying relative temperatures on temperature drop through the insulation may be seen.

In test *A* (open circuit normal voltage), the teeth and core are of higher temperature than the copper, and the drop through the insulation between copper and tooth laminations is minus one deg., while the drop through the insulation between the copper and fibre wedge is plus 11 deg.

In test *C* (one-half normal current and full voltage), the corresponding " drops " are plus 3 deg. and plus 17 deg.

In test *E* (three-fourths normal current and nine-tenths normal voltage), in which the total temperatures are approximately the same as in *C* but in which the losses are differently distributed, the corresponding drops are plus 9 deg. and plus 14 deg. These figures show that instead of the drop between copper and iron sides of the insulation being proportional to the copper loss as in Mr. Williamson's formulas (2) and (3) the drop has increased faster than the loss (due to the increased flow of

heat caused by the lower core temperature): that this drop is much less than results from these formulas (due to the other paths available for the escape of heat) and that instead of the surface of the coil adjacent to the slot wedge being ineffective in dissipating heat, as assumed by Mr. Williamson it is more effective than the surfaces adjacent to the laminations on which Mr. Williamson places the entire burden. The reason for this, of course is the lower temperature of the air gap side of the fibre wedge compared with the temperature of the laminations.

The general method advocated by Mr. Williamson is much nearer the facts than methods of temperature determination now in use, but to be of practical value the formulas and method of calculation must be based on assumptions nearer the truth than the assumptions made by the author.

If the method and formulas developed in this paper are used to obtain actual copper temperatures from the measurements of temperature by resistance coils or thermocouples outside of the slot insulation, the results will be entirely misleading except on short-circuit tests.

B. A. Behrend: The question whether the total temperature is affected by the outside temperature is of great importance. I do not believe in the most plausible and lucid explanation rendered by Dr. Steinmetz and Dr. Kennelly, and the reason why it is not correct, if I may quote Prof. Adams, is that the radiation plays so small a part in the cooling of the modern electrical apparatus, that the beautiful, simple and plausible explanation is altogether too beautiful, too simple, and too plausible to be true!

Comfort A. Adams: I specified that that was true of a machine with normally good ventilation. It would hardly be true, perhaps, in a machine totally enclosed.

Concerning the hot spot temperature I understood Mr. Schuchardt to say that the exploring coils were placed under the wedges, between the wedges and the outside of the insulation. The drop of temperature through the insulation in this case is certainly such as to render the results of tests wide of the mark. The discussion by Mr. Newbury touches upon this same subject. I cannot quite agree with him. In a two layer winding, where you have two bars separately insulated in the same slot, it is quite unlikely that much of the heat flowing from the lower bar will pass out to the surface by way of the coil above it and the wedge. The heat flow paths are in that case practically restricted to two, one through the solid insulation and the iron surrounding it and the other longitudinally to the coil ends. In a long core such as is found in large turbo-alternators, say 70 in. in length, it would take, in order to carry all of the heat longitudinally along the conductors to the coil ends, a difference of temperature of from 50 to 100 deg. cent. between the center of the conductor and the outer end, according to the current density in the copper. This difference in temperature increases with the

square of the length. It thus seems quite unlikely that any considerable amount of heat flows from the center to the ends. It seems still more unlikely that an appreciable amount of heat flows from the lower coil through the upper coil and the wedge. It must flow largely through the slot insulation. The results of Mr. Williamson's computations therefore seem to be quite reasonable.

R. F. Schuchardt: Just a word with reference to Dr. Adam's remarks with regard to the location of our exploring coils. It is true that these coils are laid between the wooden wedge and the outside insulation of the coil. It would be impracticable to put the coil directly adjacent to the high tension armature copper. The problem is to get the exploring coil at the hottest point most practicably accessible and then allow for the probable higher temperature inside, and that is the reason we set 80 deg. for the measured allowable limit instead of 90 deg., even when measured so much nearer the hot spot than is possible with old time methods.

B. F. Behrend: Suppose that the designer made a mistake and used a very heavy piece of copper; according to Mr. Burke's method of mind reading he would add 10 deg. for it, and he might equally well add 65 or 70 deg. The exploring coil may just as well be wound inside the coil. Coils should be so placed. It will help the designer and manufacturer, on the one hand, and the user, on the other hand; it would settle disputes if exploring coils could be wound inside the coil, and they should be.

Comfort A. Adams: It seems to me the explanation is the milk in the cocoanut, so far as the discussion we had this morning is concerned, and explains the recommendation of Mr. Torchio for a 75 deg. hot spot temperature, because his measurements were made apparently where the temperature was altogether likely 20 deg. or more lower than the actual hot spot temperature inside of the insulation.

Leo Schuler: I asked Mr. Schuchardt when he made the measurements by means of that exploring coil, which was outside the insulation, whether he measured the same coil by resistance, and what the relation of the two temperatures were?

R. F. Schuchardt: Our results showed about 30 deg. higher temperature with the exploring coil measured while the machine was loaded than by the resistance of the armature coil measured at the very earliest possible moment after the unit was shut down. Of course the armature temperature dropped immediately when the load was removed and while the unit was coming to rest.

Leo Schuler: Outside the insulation?

R. F. Schuchardt: Yes.

L. W. Chubb: In his discussion Mr. Durgin stated that his exploring coils were placed "some between coils, and some between coil and slot and some on the end turns." Mr. Schuchardt states that these same coils were placed "between the armature

coil and the wooden wedge," and adds that the problem is to place them in the hottest point accessible.

If the coils are located between coils as Mr. Durgin states, the difference of 30 deg. cent. between exploring coil and temperature by armature coil resistance is more probable. The temperature difference under the wedge and between the two coils can readily be seen by referring to the full load test shown under *D* in Fig. 2 on page 592. Thermo-couple No. 17 shows the temperature under the wedge and thermo-couple No. 19 the temperature between coils. The thermo-couple under the wedge is near the cool air gap; there is a great flow of heat from the coil and a large temperature drop through the insulation. Thermo-couple No. 19 is placed where there is little heat flow through the insulation and the temperature outside of the insulation more nearly approximates the copper temperature.

W. F. Dawson: I should like seriously to propose that in those machines which have two-layer windings a thermo-coil placed between the upper and lower layers will probably approximate the highest temperature in the machine. The outer coil has as a rule a greater loss than the inner coil, due to Foucault currents generated by stray flux threading the outer conductor, and this excess loss probably about compensates for slightly better ventilation which the outer coil received from proximity to the air gap. The temperatures of the upper coil and the bottom coil are approximately the same, and, therefore, there will be practically no exchange of heat between them. This middle point, therefore, should approximate the maximum temperature of the copper.

Charles P. Steinmetz: The only way of locating and measuring the hot spots would be by distributing exploring coils all along the inside winding of the high potential coil, but today, when all station operators insist on spreading high tension supply over a long distance and controlling it by low voltage, I do not think there would be any enthusiasm, on the part of stations which operate at 11,000 and 13,000 volts, to employ Wheatstone bridges, or other such apparatus to measure the coil.

As regards the relative conductivity of the alternative paths, we are at cross purposes because we speak of different types of machinery. On the one hand, one engineer has in view high voltage turbo-generators with 0.3 in. thickness of insulation, and a coil with several sq. in. of copper section, where the heat production is very large, while on the other hand, in the moderate or low voltage machines, with small coils, the conduction along the copper may be negligible compared with the heat conduction across the coil insulation, so that you see there are different classes of machines, and what applies to one does not necessarily apply to the other.

Alexander Gray: It seems to me that, if we put resistance coils next to the copper of the machine, they must be put near the neutral, and the neutral grounded.

There is another point of some interest. In a machine with a two-layer winding, the winding being well laminated so that there are no eddy currents in the conductors, the temperature of the two layers is the same, there is no flow of heat between the upper and the lower layer, and therefore a thermo-couple placed between these layers must give very nearly the copper temperature, because there is no temperature gradient if there is no flow of heat.

I want to record the case of a large machine in Montreal which has a temperature rise of 40 deg. cent., measured by thermometer on the ends, and a temperature rise of 127 deg. cent. measured by the resistance coils placed between the upper and lower layers of the windings. It is a machine with deep conductors insulated with mica. The eddy current loss in the deep conductors is very large, and there is a flow of heat from the coil in the top of the slot to that in the bottom.

B. A. Behrend: If Dr. Steinmetz means that it is necessary to distribute 11,000 volt exploring circuits all over the power house in order to get the inside temperature of a high tension generator, I venture to say that his statement is rather audacious, because you might easily put a small exploring coil in one of your high tension coils, and bring the leads back to an instrument, which you might attach to the turbo-generator in a manner similar to the method of attaching steam gages to high pressure steam turbines, without carrying high tension current all over the power house, as he suggested.

R. B. Williamson: The temperature gradient has much to do with hot spots in a long generator. The gradient through the insulation of high voltage machines is higher than many realize, and in machines having very long cores, we cannot count on much heat passing from the center of the machine out to the end.

As Prof. Adams has pointed out the difference in temperature necessary to set up a flow of heat from the center to the end, increases as the square of the length. Considering the center of a long machine, nearly all of the heat liberated in the copper must pass through the insulation to the iron. On this assumption it is possible to calculate the temperature difference between copper and iron close enough to give us some idea as to the probable internal temperatures. In the case of high voltage machines where the thickness of insulation is considerable there will be a relatively high temperature gradient, and it becomes a question to decide whether it is better to use lower voltage with thinner insulation and use step-up transformers, or use the high voltage with accompanying higher internal temperature.

B. G. Lamme: I want to refer to one point, namely, the measurement of temperature of high voltage armature coils by means of thermo-couples placed inside the insulation. I think that is all right as a research method, or one for determining temperature gradients in general. If we find by test that thermo-

couples placed between upper and lower coils in the same slot in a high voltage machine, give practically the same temperature as thermo-couples located inside the insulation, then we have gotten the information we need for practical purposes. I think therefore that the use of thermo-couples inside the insulation would be for the purpose of calibration only, and will not become a commercial method of measurement, as there are very serious objections to such an arrangement.

Prof. Adams has spoken about the very small amount of heat conducted from the middle of a turbo-generator winding to the outer end. This is true in some cases, but in all cases there is a certain amount of heat conducted out which serves to reduce the internal drop through the insulation at the hottest point. Considering that a large turbo-generator may be 50 deg. hotter in the center of the winding than in the end winding, my calculations show that, except in very extreme cases, the longitudinal heat conduction is an item which should be considered in the calculations.

James Burke: I have prepared some notes on the papers now under discussion, in which I have, I think, shown that all the results are consistent, that the corrections for difference in temperature of the surrounding medium can be made and can be made intelligently. In general, the results shown in the tests of motors, and exploring coils, and certain experimental coils, all agree with each other within a very close margin. The negative and positive results are to be expected, and I think from the data contained in these various papers that we will be able to determine exactly what temperature correction should be introduced in the Rules. I think that a temperature correction is necessary, in view of the fact that one of these papers states specifically that certain motors fulfilled a temperature guarantee in summer, and failed to fulfill the guarantee in winter, and on retest in summer fulfilled the guarantee again. So that the importance of temperature correction seems to be supported by the facts in the papers now before us.

James Burke: (by letter) In the paper by C. P. Steinmetz and B. G. Lamme, reference is made to temperature correction as follows:

"The variation of the temperature rise has heretofore been considered as having a definite relation to the temperature of the cooling medium. However, it appears that it does not follow any definite simple law, but it is sometimes positive and sometimes negative, so that no satisfactory correction for room temperature is possible at present."

Also the following recommendation is made: "No temperature correction should be made for variation of the cooling temperatures from the reference temperature of 25 deg. cent."

From the number of very interesting papers presenting data on this subject, it would appear that a satisfactory treatment of this temperature correction can be arrived at, and it seems that

the apparent confusion from the correction being sometimes positive and sometimes negative, should be fully explained.

In the existing rules, temperature correction is covered by rule No. 269, where it is stated that the correction is " On account of difference in resistance."

The adopted standard room temperature is 25 deg. cent., and the temperature coefficient for the resistance of copper at this temperature is given in appendix *E* of the present Rules, as 0.00386 for copper of 100 per cent conductivity, and this figure seems to be generally used. Taking this figure as a basis for correction, it would appear that the correction should be 0.386 per cent per deg. instead of 0.5 per cent as in the present rules.

If we consider a condition of room temperature of 40 deg. cent., which is 15 deg. above the adopted standard room temperature all the copper resistances will be 5.8 per cent higher than at the standard room temperature of 25 deg. cent. For all copper carrying a constant current, as for example, the shunt field of a generator in which the exciting current is kept constant for the purpose of maintaining constant voltage, the watts lost will be increased by 5.8 per cent. In the shunt field of a motor operated from a constant voltage supply circuit, the result of the higher resistance due to higher room temperature, is to reduce the current flowing in the circuit, and the watts lost in the circuit are reduced 5.8 per cent; thus we have an increase in the watts lost in a generator field and a decrease in the watts lost in a motor field, when the room temperature is higher than the adopted standard of 25 deg.; and for room temperatures of 40 deg. cent., the difference between a generator field and a motor field is 11.6 per cent. If a generator and motor were directly comparable, under this assumed room temperature of 40 deg., if the temperature increase on the motor field is 50 deg., the increase on the generator field would be approximately 6 deg. higher, or 56 deg. cent. If the value of the cooling medium is constant, we will then have a positive correction in the generator and a negative correction in the motor. If, however, the watts lost are kept constant rather than the current or the voltage, there would be no temperature correction if the value of the cooling medium remained unchanged, because in maintaining constant watts the increase in the resistance of the copper would be compensated for by a decrease in the current flowing.

Sometimes the fact is misunderstood, that the reason for temperature correction is due to change in watts lost on account of change in resistance, occasioned by the difference in temperature. For example, in the paper by Blanchard and Anderson, page 472, in referring to their curves of Fig. 3, which are based on keeping the watts constant, they say: " The variation according to these curves, is about 0.15 deg. per deg. cent. variation of air temperature, in the opposite direction to that assumed in the present Standardization Rules."

As pointed out above, there would be no temperature correc-

tion for constant watts, but there would be a positive correction for constant amperes, and a negative correction for constant voltage applied to a coil.

The next important consideration, is variation in the quality of the cooling medium. In the present Rules the assumption seems to be that the cooling medium is constant, or, in other words, that with some definite watts per sq. cm. the temperature increases above the surrounding air would be the same with air at 40 deg. as with air at 25 deg. In the paper by J. J. Frank and W. O. Dwyer, entitled," Temperature rise of stationary induction apparatus," it is shown that the radiation of heat is better with higher surrounding temperature, and taking a standard temperature of 25 deg. cent., the radiation value improves by 0.73 per cent for each degree increase in surrounding temperature. In the same paper it is shown that the convection becomes poorer with higher surrounding temperature. It will, therefore, be evident that the change in value of the cooling medium will depend upon how much of the heat is taken care of by radiation, and how much by convection. This influence is shown in Fig. 8 of their paper, in relation to tank dissipation, from which it will be seen that with a 50 deg. cent. increase in temperature, the correction for the cooling medium is as follows:

No convection..................	plus	0.73 per cent.
Combined radiation and convection from plain cast-iron surface..........................	"	0.51 per cent.
Combined radiation and convection from simple corrugated surface.....................	"	0.36 per cent.
Combined radiation and convection compound corrugated surface........................	"	0.21 per cent.

The foregoing figures are based on stationary surfaces, without any air circulation caused by the moving part in the machine, or caused by fan for forcing air through the machine. With air circulation, the proportion of heat dissipated by convection increases rapidly, and it is not unusual to have the effect of convection ten times as great as the effect of radiation. On the compound corrugated surface, if by air circulation the convection is made four times as great as the radiation, the improvement in radiation due to higher temperature is just counterbalanced by the depreciation in convection, so that the value of the cooling medium becomes constant. In the same way it will be seen that with the simple corrugated surface, when the convection is about seven times the value of the radiation, the correction becomes zero and the value of the cooling medium constant. Similarly, with plain cast iron surface, when the air circulation is sufficient to make the convection approximately

ten times the radiation, the correction becomes zero, and the value of the cooling medium constant.

This paper by Frank and Dwyer which contains some valuable tests, recommends for air-blast transformers, a correction of one-half of one per cent per deg. variation for 25 deg. cent., which incidentally is the same correction as in the present A. I. E. E. Rules. This is only recommended for air blast transformers and not for other types of transformers.

In the paper by Blanchard and Anderson, the test shown in Fig. 3, curve 3, for air pressure of 760 mm., figures out a negative correction of approximately 0.3 per cent per deg. This is for a coil suspended in still air and is probably comparable with a simple corrugated surface. The deduction which I have made from the paper of Frank and Dwyer, shows for a simple corrugated surface a negative correction of 0.36 per cent per deg., so that it is a substantial agreement.

In the paper by C. E. Skinner, L. W. Chubb and Phillips Thomas, entitled "Effect of Air Temperature, Barometric Pressure and Humidity on the Temperature Rise of Electrical Apparatus," tests are given on a coil maintained at constant watts of approximately 32, and with air circulation for the purpose of cooling the coil. These tests are tabulated in table No. 1, and show that the increase in temperature of the coil was practically constant throughout a range of temperature of the cooling air, of from 30 deg. to 64 deg. If the coil is considered as a simple corrugated surface, then their test agrees with the deductions which I have made from the paper of Frank and Dwyer, with a convection value of seven times that of radiation. From the description of the arrangement for this test and the blower for putting the air through the testing box, this amount of convection in relation to radiation would be easily expected, and therefore there is substantial agreement.

From the tests of Skinner, Chubb and Thomas, above referred to, where they show practically zero correction for a large variation in air temperature, and with constant watts, it is evident that if this coil were carrying a constant current it would have a positive correction of 0.386 per cent per deg. cent., and if it were working under a condition of constant voltage applied, it would have a negative correction of the same amount.

The paper by Maxwell W. Day and R. A. Beekman, entitled "Effect of Room Temperature on Temperature Rise of Motors and Generators," shows some interesting tests from which deductions can be made.

The results given in this paper are based on tests which appear to be at constant speed; for example, Figs. 4, 5, 6, 7, 8, and 9, are all marked "825 rev. per min." However, the description of the test shows that they were operated at constant voltage. The average difference in final temperature of fields between the low temperature test and the high temperature test in each figure is about 21 deg., which would make about 8 per cent differ-

ence in field strength, due to the higher resistance and consequently less current in the fields. This would result in a speed difference of approximately 4 per cent. As most of these tests were with fans for circulating air through the motor, and apparently the fans directly connected to the motor, this difference in speed would make a great difference in the amount of air circulated, as the amount of air circulated by a fan increases very rapidly with increasing speed of the fan. It would appear therefore, that at least part of the negative temperature correction in all these figures could be accounted for by a higher speed of motor due to the weaker field with higher temperature, and consequently increased air circulation.

Taking the figures from Figs. 4 to 12 in the said paper, and considering the bearing temperatures, the average of all the bearing temperatures is a correction of minus 0.75 per cent. If these bearings are considered as plain cast-iron surfaces, we would have a comparable figure from the deduction made from the paper of Frank and Dwyer of minus 0.51 per cent. The probable difference in speed of 4 per cent would make a difference in torque at the same load of about 4 per cent, which would mean less pressure on the bearings and consequently negative correction. If this is taken at 0.2 per cent per deg. which is figured from the average temperature, and deducted from the 0.75 per cent average from the test, the difference is 0.55 per cent, and is comparable with the 0.51 per cent for plain cast-iron surface referred to, thereby approaching substantial agreement.

Similarly, the average of all frame temperatures gives a correction of 0.46 deg. per deg. and agrees very closely with the 0.51 per cent per deg. for plain cast-iron surfaces.

Considering now the correction for shunt field by resistance, averaging all the tests shown in table 1, we get a negative correction of 0.31 per cent per deg., and similarly the average for shunt field by thermometer is 0.389 per cent per deg. These figures are directly comparable with the present A. I. E. E. rules of 0.5 per cent per deg., which, as pointed out, is based on the temperature coefficient of copper should be 0.386 per cent per deg. The average of the two methods of tests, namely, by resistance and by thermometer, is 0.354 per cent per deg., which is very close agreement with the temperature coefficient of copper, namely, 0.386 per cent, and can be considered in substantial agreement.

In the paper by Day and Beekman, an attempt is made to draw some average from commercial tests, for example, Fig. 13, which shows the armature conductors' temperature increase on 98 machines, which are supposed to be alike. In these tests there are thirteen machines tested at 20 deg. cent., room temperature, and the tests appeared to show temperature increases varying from 23 deg. to 38 deg., or a variation of 65 per cent in the increase in temperature. Similarly, in Fig. 15, out of 11 machines tested, at a room temperature of 20 deg. cent.,

the shunt field temperature increase varies from 22 deg. to 45 deg., or over 100 per cent variation. It would therefore seem that any conclusion of averages drawn from these commercial tests should be avoided.

From all the foregoing and from the information contained in the various papers, it would seem that the present rules can be corrected so as to give a fairly accurate basis for temperature correction. The argument against continuing a temperature correction in the rules, seems to be that it is too close a refinement when the large variations in actual temperature measurement are taken into consideration. Nevertheless, the great importance of accurate determination of temperatures, will doubtless bring about more care in this direction and better agreement between tests in the future, and probably also better methods of taking temperatures. As pointed out, the difference between a dynamo field temperature and a motor field temperature may be as much as six deg. at a surrounding room temperature of 40 deg., and yet have no difference at 25 deg. surrounding temperature, and it would seem that such a large difference should not be overlooked.

The importance of establishing proper rules for temperature correction is brought out very strongly in the paper by Day and Beekman, from which I quote:

" In one particular case some motors were tested in the summer and easily met the specified heating limits, but when the customer installed them in the following winter, and tested them, some of the heating limits were exceeded, while on retesting them again in the following summer the machines again easily met the specifications."

Now in this particular case, on account of not applying proper temperature corrections, the heating limits were exceeded. In other words, it appears that the machines did not fulfill the specifications. This might have been a cause for rejection of the machines, and yet the trouble was not with the machines, but was in not having a proper rule for correction.

If the motors in question were totally inclosed machines without forced draft ventilation and operated in a summer temperature of 35 deg., with an increase in temperature of 50 deg., then operated in a winter temperature of zero, the temperature increase might become 66 deg. for the shunt field, on account of increase in watts, due to more current flowing in the shunt fields, and also on account of decrease in quality of the cooling medium. In the assumed case, the correction for cooling medium was taken at the same as for plain cast-iron surface, namely, 0.51 per cent., which would probably be correct on account of being an enclosed motor and not having air circulation to increase the effect of convection.

In this assumed case with 35 deg. air temperature and 50 deg. increase, the ultimate temperature would be 85 deg., whereas with zero air temperature and an increase of 66 deg., the ultimate

temperature would be only 66 deg. Therefore the motor would be perfectly safe, but would not be filling a temperature specification of 50 deg. increase unless some temperature correction were applied.

If the motor in question was not a fully enclosed motor, or if it had forced circulation, the lower temperature would result in stronger fields and probably about 14 per cent difference in the amount of air circulated through the motor. So that the temperature increase would be greater, not only on account of increased watts in the field, but also on account of much less air being passed through the machine for cooling it. This condition might readily result in the shunt field having an excessive increase of temperature compared with specifications, unless some temperature correction were applied.

Charles P. Steinmetz: I wish to say that when the Committee recommended not to make any temperature corrections, it was under consideration that the previously used temperature correction was incorrect, and that the evidence thus far available shows that there is a change of the temperature rise with the room temperature, but that no law has yet been derived from these tests. Since we have not yet been able to formulate a law, all we can do is to say that in testing we shall, as closely as possible, try to get the room temperature near the standard temperature.

A. E. Kennelly: I think it is a very interesting fact that the Standardization Rules are encountered by a question of pure science as to what is the law of the dissipation of heat energy from a heat body of a given form, and it is a remarkable fact, also, that whereas steam engineers are constantly investigating the laws of heat, for determining the input capacity of their machines, in order to utilize the heat, we are faced with the opposite difficulty of finding how far we can dissipate heat, and get rid of it. It is curious that heat should be the common science upon which we both find limitations.

In regard to Dr. Langmuir's paper, he proposes a very interesting method for determining the dissipation by convection from a hot body. He proposes to consider for example, that a round stationary wire which is heated by an electric current that the air carries a layer or sleeve of stationary air around it, that the heat is conducted through that stationary layer, and then dissipated in any manner you please beyond that stationary sleeve. This hypothesis is likely to conflict with fact. We think there is evidence to show that the air is not stationary in the immediate neighborhood close up to the hot wire. Dr. Langmuir's formula if it will give us correct answers may be of great value to us, but it does not follow that the physical facts are in accordance with this hypothesis even if the formula based on this hypothesis gives correct results.

In regard to dissipation of energy by free convection, in our paper presented before the Institute three years ago we first showed that when a thin wire was subjected to forced convection

in air, quadrupling the speed of convection doubled the convected power, and that has been since corroborated by Prof. Norris in England. It was later discovered in the archives of a French Society that Boussinesq had originated a formula leading to this result. Dr. Russell has recently developed Boussinesq's formula in practical form, and has shown that the heat should dissipate as the square root of the pressure as well as the square root of the velocity. We have lately checked this by experiments not yet published.

L. W. Chubb: In our paper on temperature rise, the curve of Fig. 2 shows a constant rise at all temperatures. This result seems to be somewhat contradictory to some of the other papers. In these tests the temperature of the walls was kept the same as that of the cooling air and if there is any difference in convection due to the change in the viscosity of the air, this difference must be small, with forced convection, and be offset by the fourth power law of radiation through equal range of temperature at higher temperatures, within the range of temperature shown.

In the tests the ratio of dissipation by convection to radiation was very high, and if there is any great difference in convection at different temperatures, it would certainly more than offset the change in radiation.

The same apparatus illustrated was changed so that the cubical box consisted of glass plates. In this case the radiation to outside objects at ordinary temperatures caused a much lower temperature rise above the circulating air, when the air was at high temperature. This shows that corrections of temperature rise should not be based on air variations from 25 deg. cent. alone, and that the temperature of surrounding walls and objects will have a greater influence than the air variations.

If corrections are to be based on variations of air temperature alone the manufacturer can profitably entertain his customer's witness in a palm garden and do his testing in a glass conservatory where the air temperature will generally be high and most of the radiation will be to space at absolute zero.

Selby Haar: Dr. Langmuir gives a number of data on thermal conductivities and resistivities of various materials but I believe he has overlooked a series of researches by a German physicist, Dr. Nusselt, whose method seems to be quite worthy of study. He used two concentric spheres between which he put the heat insulator which was under investigation, and he also was able to study the differences in the heat resistivities at various temperatures.

Leo Schuler: In regard to the influence of air temperature on the rise of temperature, Mr. Burke says that he has worked out a method of taking this into consideration. According to theory, and also according to the experiments shown in the paper, the influence of air temperature will be the more pronounced the more heat is taken away by radiation, though the difference will be probably greater in an enclosed motor, as is also shown in

the paper, while, for instance, in the large turbo-generator where all the heat is taken away by convection, by air, there will be practically no difference. Could not Mr. Burke give us some idea how he proposes to take this into consideration for the correction to be made in the rules?

James Burke: That is covered in my written discussion.

E. W. Stevenson: Dr. Kennelly was the author of a very useful and interesting table, published twenty-five years ago, upon the carrying capacities of cables, in which he laid particular emphasis upon the fact that a dull black color on the outer surface made the carrying capacity of this conductor very much more than what it was if it were polished or bright.

I would like to ask Mr. Dushman if in making his experiments, whether he tried the value of the different colored pigments on the outside of cables carrying overload currents, and if in doing so there were any differences in the carrying capacity of these cables? Of course, it is understood that these cables are all hanging in the open air. It is possible there would be no difference with cables lying in ducts, whatever their color is.

R. W. Atkinson: I wish to confirm what has been said by Mr. Dushman about specific heats. We have looked up data for a good many materials and have tested a number of others, and find these figures are closely the same for the different materials and about of the value given.

I wish to mention that we have obtained considerable additional data since preparing this paper, which will be published in the PROCEEDINGS in a form which will make our data of much more practical use. I wish further to state what has been the basis of the formulas and equations which we have given here. These are all a result of actual tests, careful measurements have been made with thermometers and thermocouples of the temperature rise of many different sizes and types of cables. For convenience, greater accuracy, and brevity we put these in the form given in our paper.

R. W. Atkinson (by letter): It is desired first to call attention to some slight corrections to be made in our paper. On page 571, in the formulas for short time carrying capacity, the exponent of (10) is $ta/2.3$ and $ta/2.3r$ instead of $2.3\ ta$ and $2.3\ ta/r$. On pages 569 and 570, the constants "b" and "a" give the temperature rise in degrees fahr.; these should be divided by 1.8 to give temperature rise in degrees cent. In order that these constants may be compared with other constants which are presented at this time, we may state that they correspond to a thermal restivity of approximately 1000 cent. degrees per watt per centimeter cube, and to 1200 degrees per watt per square centimeter, respectively. The neglecting of temperature coefficient in the formulas, means that we assume that the negative temperature coefficient of heat resistance approximately balances the coefficient of copper ohmic resistance.

Since preparing our paper, we have made a number of further

tests, and have correlated our result so that they may be conveniently applied to determining the temperature of cables installed in underground conduit system. We are giving this data for predetermining both the ultimate temperature rise and for determining the temperature with loads of comparatively short duration. Reference will be found in what follows to some of the other papers published in the February PROCEEDINGS, and also to a paper by C. T. Mosman published in the May, 1912 PROCEEDINGS.

The formulas and equations which we have given, and the tables which we give herewith, with one exception which will be mentioned, are a result of direct test, careful measurements having been made with thermometers and thermocouples, also a few by rise of resistance method, of the temperature rise of many different sizes and types of cables. For convenience and brevity, and to increase the range of application, we have put these in the form given.

Table III, herewith, shows the current necessary to produce a rise in temperature above surroundings, of 25 deg. cent., for cables insulated with 1/8-in. (3.17 min.) saturated paper and covered with a bright new lead sheath. The constants used are those just mentioned. The rise of temperature of a cable above a duct wall surrounding it is the same as the rise of the same cable in free air. This is indicated in the theory given in Langmuir's paper and is also borne out by tests made by us. As stated, the value assigned to *a* is correct for a new bright sheath, either in air or in conduit. This value indicates that the radiation from the sheath is about one-third of that from a perfect "black body." Painting the sheath black will reduce the temperature rise of the sheath from 20 per cent to 25 per cent below the value used in the table. It is indicated by Langmuir's theory that, depending upon the relation in size of the cable and the enclosing duct, the rise of the sheath might be increased slightly or considerably reduced below the value given, but we do not believe either condition likely to become important. The value given for *b* is a safe value for ordinary paper or varnished cloth cables. Our tests show, in most cases, a rise of copper above lead of 10 per cent or 15 per cent less than this, but it is believed that this value is as low as it is safe to use. The value given for varnished cloth by Dushman is 25 per cent lower than this. The same author gives a value for rubber which is 63 per cent of the value given here for paper. Table III should be used as given, for ordinary cases, and for those cases where it is not necessary to use absolutely the maximum allowable capacity. The values given will always be safe for the thickness of insulation given. Table IV gives correction factors for various thicknesses of insulation and shows how the total difference of temperature between copper and the surroundings of the cable are distributed, and thus makes it possible to make use of the correction factors given above where it is desirable and necessary.

It will be noted that the total temperature rise is very nearly constant with the various thicknesses of insulation given.

Tables V and VI correspond to tables numbered III and IV respectively, tables numbered V and VI being for three-conductor tables.

TABLE III.—SINGLE CONDUCTOR CABLE

CURRENT REQUIRED TO PRODUCE 25 DEG. CENT. RISE ABOVE SURROUNDINGS, AND WATTS LOST PER FOOT

Size B. & S. G.	Cir. mils	Safe current in amperes	Watts lost per foot at 66 deg. cent.
14		22	1.45
13		26	1.58
12		29	1.59
11		34	1.58
10		38	1.66
9		44	1.86
8		51	1.97
7		58	2.00
6		67	2.03
5		77	2.14
4		89	2.21
3		103	2.31
2		119	2.51
1		138	2.58
0		159	2.90
00		185	3.12
000		215	3.37
0000		250	3.62
	250,000	279	3.75
	300,000	314	3.98
	400,000	381	4.40
	500,000	442	4.74
	600,000	501	5.07
	700,000	555	5.30
	800,000	610	5.61
	900,000	661	5.90
	1,000,000	712	6.15
	1,100,000	759	6.32
	1,200,000	807	6.55
	1,300,000	851	6.73
	1,400,000	895	6.95
	1,500,000	941	7.17
	1,600,000	984	7.34
	1,700,000	1024	7.50
	1,800,000	1063	7.58
	1,900,000	1112	7.89
	2,000,000	1149	7.94
	3,000,000	1500	9.10
	5,000,000	2100	11.6

Having now the temperature rise of the copper of cable above the duct walls, we will give data for determination of the rise of the duct walls above the surface of the earth. On account of the many variations which may occur with different types of duct system and laid in different kinds of earth which is itself at

various and somewhat unknown temperatures, we believe that a direct measurement of duct temperature in combination with the data given above is the practical method of determining temperatures of existing installations. For purposes of previous calculations of new installations, we present herewith results of tests in a form for future use. Tests recently made by us show a difference of temperature between the inner and outer walls of a terra cotta duct 0.8 in. (2 cm.) in thickness to be 0.35 deg. cent. per watt of actual loss per foot length of conduit. These tests were made upon $3\frac{1}{4}$-in. (8.25 cm.) conduits and the difference in the temperature given being that through a single wall. We may thus consider that the temperature of the outside wall of the duct is lower in temperature than the inner wall by 0.7 deg. cent. per watt per foot. This is on the assumption that the heat from the cable is radiating freely from each of the four

TABLE IV. SINGLE CONDUCTOR CABLE

A—Rise in temperature attained with current in table III.
B—Rise of sheath in per cent of total rise.

Size B. & S. G.	Cir. mils.	4/32 Paper A Deg. cent	4/32 Paper B Per cent	8/32 Paper A Deg. cent.	8/32 Paper B Per cent	16/32 Paper A Deg. cent.	16/32 Paper B Per cent
14		25	52	25.6	36		
11		25	56	25.7	38	27.4	23
8		25	59	25.8	41		
2		25	66	26.4	47		
0		25	68	26.5	50	30.1	32
0000		25	70	26.9	52		
	500,000	25	73	27.5	56		
	1,000,000	25	75	28.2	58	33.6	38
	2,000,000	25	76	29	60		

walls. In order to measure the temperature of the duct walls surrounding any cable, it is necessary only to measure the temperature in an adjacent idle duct at the same distance from the outside of the conduit or the temperature of a duct adjacent but nearer the center of the conduit system. In the former case, the temperature of the idle duct will be lower by not more than a very few degrees which can be estimated from the data just given and in the latter case the temperature of the idle duct will be very nearly the same as the walls of the working duct. A still more satisfactory way of measuring the temperature of the duct wall is to make the measurement actually within the working duct, but *after cutting off the current from the cable* within for from one-half hour to two hours. This allowable on account of the great amount of time required by the duct system to change in temperature as compared to the time required for the cable to

change. If measurement of cable within a working duct is taken when there is a great difference between the temperature of the sheath and the temperature of the duct walls, it is obvious that it is not known which temperature is being measured. With any number of cables distributed throughout any duct system, the rise of the system above the surface of the earth is quite closely proportional to the total energy dissipated in all of the cables. With any given type and size of conduit construction, we may say that the temperature rise of the system is

TABLE V.—THREE-CONDUCTOR CABLE INSULATED WITH 3/32 PLUS 3/32 PAPER

CURRENT REQUIRED TO PRODUCE 25 DEG. CENT. RISE ABOVE SURROUNDINGS

Size	Cir mils.	Safe current in amperes	Watts lost per foot at 66 deg. cent.
14		17	2.6
13		19.5	2 7
12		22	2.7
11		25	2.8
10		29	2.9
9		33	3.1
8		38	3.3
7		43	3 3
6		50	3.4
5		57	3.5
4		66	3.7
3		76	3 8
2		88	4 1
1		101	4.3
0		117	4.7
00		136	5.0
000		158	5.5
0000		183	5.8
	250,000	204	6.1
	300,000	231	6.5
	400,000	278	7.0
	500,000	322	7.5
	600,000	363	8.0
	700,000	402	8.3
	800,000	438	8.6

equal to a certain number of degrees per watt lost per foot of duct structure. The tests previously referred to, made by one of the authors at Niagara Falls, indicate that the rise in temperature of the outer duct of a 12-duct system is equal to 0.67 deg. cent. per watt loss per foot of structure. The rise in temperature of a duct not adjacent to the earth may be taken as 0.8 deg. per watt loss. Mosman's tests on page 775 of the May PROCEEDINGS give data for calculating the temperature rise of a conduit system containing 81 ducts. This is a fibre conduit laid in concrete. The center duct contained no cable and the

rise of this and the nine surrounding it can be taken as 0.35 times the total watts lost in the system. The temperature rise of the surrounding rows taken in order may be taken respectively as 0.29, 0.21, and 0.13 deg. cent. per watt lost per foot of structure. Sufficient data are not available to make a good generalization.

Very often, a formula similar to that given by the authors has been given for the temperature rise of cables carrying currents for short periods. With the formula as a starting point and based on the assumption that the insulation takes the heat with the same rapidity as the copper conductor, theoretical curves have been deduced showing the temperature rise after various lengths of time. Probably the error due to this wrong assumption is seldom very large. The data given in the paper of the authors are based on tests of a number of different sizes, varying from No. 6 to 1,000,000 cir. mils. These experimental

TABLE VI. THREE-CONDUCTOR CABLE

A—Rise in temperature attained with current in table V.
B—Rise of sheath in per cent of total rise.

Size B. & S. G.	Cir. mils.	$\frac{3+3}{32}$ Paper		$\frac{8+8}{32}$ Paper	
		A Deg. cent.	*B* Per cent	*A* Deg. cent.	*B* Per cent
11		25	58	21.2	35
5		25	59	23	37
0		25	61	25.7	37
	500,000	25	62	29	39

results were then put in a form closely resembling the simple theoretical formula, thus largely combining the advantages of pure theory and pure experiment. We believe that our data can be expressed in a form somewhat more convenient for some uses, as given in Table VII. We have made one or two small corrections. This table shows the length of time required for different sizes of cable to reach different percentages of final temperature change, after an alteration in current strength. The data are so given that the temperature rise due to excessive overloads for short periods can be computed. If a steady current has been flowing, and an additional current is suddenly applied, the table is applicable to the temperature change due to the change in current. We do not advise application of these data to conditions which will actually cause a rise greater than that normally allowed; however, in the calculation of the final temperature rise to be used in connection with the table, one should neglect the temperature coefficient, simply assuming the final

temperature rise for any current to be proportional to the square of the current.

The data so far given for short time temperature rise of cables apply to the rise of temperature above the surroundings. The heat capacity of the duct structure for underground cables, is very great as compared with the heat capacity of a cable itself, and consequently the temperature rise of the duct structure is very slow. There are not enough experimental data to make general applications. Table VIII is computed on the assumption that the only portion of the duct structure to store heat from the cables is that portion of the duct structure immediately surrounding the cable. This is far on the safe side, as shown by theory and by the results of some tests which have been compared with these tables. If it is desired to apply these tables to learn how long an experiment on an underground structure must be carried on to reach a steady temperature, it would be well to

TABLE VII

B. & S. G. or cir. mils	Time in minutes with 5/32 insulation							Bare
Per cent of final rise	10%	20%	30%	50%	70%	80%	90%	10%
6	0.52	1.2	2.4	5.3	11	16	30	0.38
4	0.66	1.6	2.8	6.6	14	21	35	0.47
2	0.90	2.1	3.8	8.5	19	30	40	0.63
0	1.2	3.0	5.5	12.5	25	37	55	0.9
000	1.8	4.5	8	18	37	50	72	1.2
300,000	2.9	7.2	12	25	48	65	92	2.0
500,000	4.0	9.8	16	31	57	78	115	2.8
1,000,000	6.8	15	24	49	85	120	165	4.7
2,000,000	9.5	21	34	67	115	155	230	7.0

Time required to reach various percentages of final temperature change. Time for bare conductor to reach 50 per cent and 90 per cent of change is 6.6 and 22 times as long, respectively, as to reach 10 per cent of final temperature change.

double the length of time given in the table. The columns in the center of the table (2*a* and 2*b*) may be taken as representative of most duct structures where the rise of the structure itself is important.

In order to make tables of carrying capacity of general use it is necessary to base the tables upon conditions which cause only the true ohmic loss in the conductors. This makes the tables true for all ordinary conditions. However, conditions do arise which increase greatly the losses, and these must sometimes be taken into account. The effect of dielectric loss has already been mentioned. Other losses which occur are analogous to certain losses which occur in various electrical machinery. Skin effect has been thoroughly treated in many places. When a single conductor cable carries alternating current, if there be a lead sheath, there may be a very considerable loss induced in that sheath. This is treated and curves showing its amount are

given in a discussion by the writer in the March PROCEEDINGS, 1913, on page 818. There is another loss which may sometimes occur but which under almost all ordinary circumstances, is insignificant. Alternating current flowing in any conductor produces a field in adjacent conductors and a resultant eddy current loss. If there is already a current flowing in the other conductor, this merely constitutes a distortion of the distribution of the current, but the effect upon the loss is the same. To show the magnitude of this, we may state that in a cable of 2,000,000 cir. mil. cross-section enclosed in a sheath of lead having a diameter of 3 in. (7.6 cm.) and a thickness of 1/8 in.

TABLE VIII

PER CENT OF FINAL TEMPERATURE ATTAINED WITH LOADS OF DIFFERENT PERIODS

Column "a" for first application of load
Column "b" for loads repeated daily.

Time in hours	1-*a*	1-*b*	2-*a*	2-*b*	3-*a*	3-*b*
1/2	12	12	6	6	3	3
1	22	22	12	12	6	6
2	40	40	22	23	12	12
3	55	55	31	32	17	18
4	64	64	40	41	22	25
5	72	72	47	48	27	31
6	79	79	55	56	31	36
7.5	85	85	62	64	38	46
10	92	92	72	75	47	63
15	97	97	85	87	62	75
20			92	97	72	87
24			95	100	79	100
30					85	100
48					95	100

Columns 1 are for system where one watt loss per foot in each cable causes 16 deg. cent. rise of duct structure.

Columns 2 are for system where one watt causes 8 deg. rise.

Columns 3 are for system where one watt causes 4 deg. rise. The time constant will not be shorter than this for any system.

(3.1 mm.) is placed immediately adjacent to a cable of similar construction, a loss will be induced in the lead sheath of one by 60-cycle current in the other, of about 10 per cent of the ohmic loss in the one carrying current. It is possible for the loss in the copper conductor, induced in the same way, considerably to exceed this, unless the resistance between strands is unusually high. This loss is proportionately less when the absolute dimensions are smaller, and also varies as the square of the distance between centers and inversely as the square of the frequency. It will be seen that this is ordinarily insignificant. It must be borne in mind that, wherever any of these losses occur, allowance must be made in computing the temperature rise and the

resultant carrying capacity. This last-mentioned and usually insignificant loss must not be confused with the loss which occurs when the sheaths are connected together (see March, 1913, PROCEEDINGS. This may exceed the conductor I^2R.

H. M. Hobart: Am I right in stating that Dr. Langmuir can tell fairly correctly what would be the temperature correction for any electric machine? Could he not, in a fairly reasonable space of time, figure out what the temperature correction should be?

S. Dushman: I believe he could, especially by taking into account the total losses as being due to the convection through the film and the radiation; taking that into account he can figure out the loss in each case, and I believe Dr. Langmuir will probably differ with what was said about the evidence being contrary to the existence of the film, because he has found evidence to confirm his theories.

H. M. Hobart: The impression I gained from conversation with him was that he could tell you not only whether the temperature correction was positive or negative but that he could state its value.

C. Fortescue: Referring to the use of an idle unit recommended in the paper by Messrs. Johannesen and Wade, I think an idle unit is a very good thing, but there are some cases where one cannot always get an idle unit. I think the Standardization Rules ought to specify some method of determining the correct basis of air temperature without an idle unit. The idle unit can be used when one is available. It is a splendid method, but when one cannot be had and room temperatures are unsteady, there is always a tendency for a controversy between the representative of the purchaser, witnessing the test, and the man in charge of the test. One wants to take one plan of determining his room temperature, and the other wants to take another plan. Of course, the purchaser's representative usually wants to see as high a rise as he possibly can; he wants to be on the safe side, he wants to feel that he is showing up the apparatus, and naturally he looks at the figures that are higher as being correct. This paper by Johannesen and Wade shows distinctly that the highest figures are not the correct figures, and that some method of obtaining the correct figure must be indicated.

John J. Frank: Commenting on the last paper by Mr. Fortescue, and on the paper by Messrs. Johannesen and Wade, I would like to call your particular attention to the importance and necessity of recognizing the standard method of obtaining the room temperature or the temperature for correcting the rise under load or operating conditions. The use of an idle unit to determine this basis is clearly brought out by Messrs. Johannesen and Wade. It is recognized also by Mr. Eden in the paper presented by Messrs. Rice and Eden.

In the paper by Messrs. Fortescue and McConahey, no recommendations are offered, simply a reference to probable

errors which might affect the test. Reference is made to the temperature rise of oil-insulated water-cooled transformers and the statement that the temperature of the air does not effect the cooling. This, of course, is not strictly correct, as the temperature of the air will affect the cooling of small units.

I would suggest that the over-potential test referred to should be the last or final test given the apparatus. This would insure the detection of any possible defect in the transformer created by other previous tests.

J. M. Weed: I would differ from Mr. Frank in regard to using the same method for determining equivalent room temperature in all cases, that is, with all classes of apparatus. What we really wish to find is the effect of room temperature upon the apparatus that is being tested. That is, if the room temperature is not constant, we want to know what room temperature to compare the final temperature of the apparatus with. The variations in the room temperature will affect different classes of apparatus under test quite differently. For instance, in transformers we have a large body of oil which must change its temperature, due to changes of room temperature, whereas in the case of rotating machines, etc., the active materials come in direct contact with the air and are affected more quickly than the transformer, so that, although the small oil-cup might be a satisfactory method for determining the equivalent room temperature for apparatus where the active materials come in direct contact with the air, it would not be for transformers, and in order to get an estimate of the equivalent room temperature with respect to transformers we need a large body of oil which will take time to change its temperature equivalent to the time required by the transformer itself.

W. F. Dawson: I question the theory of Mr. Weed as to the rate of cooling of the transformers after the load is taken off. I have worked with approximately the same figures expressed "amperes per sq. in.," but it would seem that he has assumed falling temperature gradient based on thermal capacity of the copper only. My experience suggests that thermal capacity of surrounding insulation material in the core and a portion of the cooling oil has also to be considered and that the falling temperaature gradient is, therefore, much less steep. The thermal capacity of copper alone is such that at an ordinary temperature, with a density of about 1100 amperes per sq. in. there will be a temperature change of one deg. cent. per min. Generally, due to added thermal capacity of insulation and other surrounding media, there will be a divisor ranging from 2 to 4, according to circumstances. For example, a transformer may be running with 2200 amperes per sq. in., but instead of four deg. cent. change per minute, there will be two deg. change or less.

C. Fortescue: I want to remark that the difference in temperature between the top and bottom oil of the idle unit, which Mr. Weed has laid some stress upon, is only a matter of perhaps two or three deg., and the error, if we take the average of the

two readings as the recommended temperature, is inaccurate only to a fraction of a degree.

J. M. Weed: Answering the question brought up by Mr. Dawson, I did not mention the calculation by the thermal capacity of the copper as a means of determining the temperature drop, but in connection with the increase in the losses during the time that copper loss measurements were being made. The same considerations will apply, however, to the temperature drop after the load is taken off, as pointed out in one of the papers, but this calculated rate of temperature change would apply only to the first instant with accuracy. This rate will begin to change at once, so that this correction would be too large if applied to any considerable interval of time. For the first minute or two it would be approximately correct. In the heating up of the copper, the heat is all stored in the copper at the start until the copper rises in temperature, and begins to throw heat out into the surrounding insulating material and oil. Likewise, when it begins to cool, the heat is given out of the copper at a certain rate and continues to go out of the copper at that rate until the difference in the temperature between the copper and surrounding material has been reduced. Of course, that is a very short time.

In regard to Mr. Fortescue's last remarks in regard to the difference in temperature between the top and the bottom of the idle transformer, I did not mean to lay stress on that consideration but was merely pointing out the possibility of not getting perfect results, but the idle transformer is so much better than any other method we have of getting an equivalent room temperature, that I have only favorable recommendations for it.

C. Fortescue: There is one point I want to bring out in connection with one of the papers read yesterday, Paper No. 10 by J. J. Frank and W. O. Dwyer, entitled "The Temperature Rise of Stationary Induction Apparatus." The paper states that if radiation is taken into account the temperature rise of the transformer instead of increasing with increased room temperature decreases. The paper says, furthermore, that the convection introduces a factor which causes the temperature rise to tend to increase with increasing room temperature. The paper also goes on to say that the temperature gradient through the insulation introduces a factor which causes this gradient to decrease with increasing room temperature, and later on in the paper a correction is given based on the increase in viscosity of the air temperature of 0.04 of one per cent, or thereabouts, per deg. cent. to be subtracted when the room temperature is above 25 deg. cent. It appears to me that the authors of the paper have lost sight of the very points which they first bring out in their paper, namely, the fact that the cooling of such a transformer takes place in two stages; first of all, the surface of insulation is cooled by convection, so that with increase in room temperature the surface for a given pressure of air has a higher

rise above the incoming air than with a lower room temperature. Secondly there is the temperature gradient through the insulation, which is a considerable part of the temperature rise in an air-blast transformer, and decreases with increasing room temperature.

In my opinion, these two factors will practically cancel each other, and instead of a correction of 0.04 of one per cent, to be subtracted for increasing room temperature, in order to bring it down to 25 deg. cent. standard room temperature, it will be zero, or thereabouts. In fact, the correction will vary with different transformers, and a good average condition would be obtained by eliminating it entirely.

Carl J. Fechheimer (communicated after adjournment): There seems to be a tendency among the engineers who have discussed the papers, as well as among the authors, to abandon the use of a temperature coefficient, since tests which have been made indicate to some extent that the air temperature has little influence upon the final temperature of the apparatus. I do not believe this stand to be correct. It is quite evident that if the loss occurs in copper only and the current in the conductors is maintained constant, the resistance and therefore the final temperature will be influenced by the air temperature. For example, such is the case with our ordinary field coils, and I believe that for apparatus of this character the proper temperature correction should be allowed: approximately 0.4 per cent per deg. cent.

It is of importance on apparatus having copper and iron loss, on which accurate tests are desired, to determine how much of the temperature rise is due to copper loss and how much to iron loss. At one time it was believed that the temperature rise was proportional to the sum of these two losses, but this has been found to be very much in error. Mr. A. M. Gray* showed conclusively that the influence of copper loss upon temperature rise in induction motors was generally considerably more than that due to iron loss, even when the two losses were equal. The reasons therefor we shall not give at the present time. Hence, there should be a temperature correction in the case of copper loss the same as with the field coil, but it is doubtful whether there should be a temperature correction in the opposite direction in the case of iron loss, due to the fact that the eddy loss decreases with increasing temperature. This would involve so much difficulty in the determination of the relative values of hysteresis and eddy current losses that it is better to omit such a correction. Even though the exponential curve of core loss is plotted, the value of the exponent would not necessarily be a criterion of the relative values of hysteresis and eddy currents, because we have found in many cases when plotting on logarithmic paper, core losses against voltage, below the saturation point, that the exponent was greater than 2, although

**Heating of Induction Motors*, TRANSACTIONS, A. I. E. E., 1909.

we know that a considerable portion of that loss was due to hysteresis.

We can easily determine the relative values of the temperatures due to iron loss and copper loss by operating the apparatus first without load at normal voltage, so that we have little or no copper loss and normal iron loss, and then operating with full load current in the windings at considerably reduced voltage (short-circuit in the case of generators, d-c. motors or transformers; and increased slip or against rotation in the case of induction motors.) It will usually be found that the sum of the temperatures obtained by these two methods is slightly greater than the full load temperature measured under normal operating conditions.*

The statement has been made that the increment in resistance due to the higher air temperature would not generally augment the final temperatures, because more heat is dissipated by radiation at the higher temperatures in accordance with the well-known radiation law. This would undoubtedly hold if a large proportion of the heat were dissipated by radiation. We do not believe, however, that much of the heat is carried away by this means. Certainly in moving machinery the greater proportion of the heat is dissipated by convection and a negligible percentage by radiation. Even in such stationary apparatus as transformers and rheostats, most of the heat is carried away by air close to the hot exposed surfaces; this air rises and is displaced in turn by cold air which takes the place of the hot air which has risen. In this way currents of air are set up, affording excellent means of dissipation by convection. Anyone who has held his hand above a rheostat carrying current has felt the currents of hot air rising from the apparatus. We could determine experimentally how much heat we could dissipate by radiation and compare with the standard methods of combined radiation and convection by enclosing the apparatus in a chamber which is ordinarily sealed and drawing a vacuum within this chamber. If this apparatus is then operated in a normal way all of the heat will be dissipated by radiation. We could then open a door at the bottom and top of the chamber and force air at various rates through the apparatus and could then quite easily determine the relative influences of radiation and convection.

Paul MacGahan (communicated after adjournment): Referring to the question of temperature indication, it should be pointed out in connection with the " exploring coil " or " resistance thermometer " method, that in cases where a continuous indication is desired for control purposes, such as where temperature indicators are to be used on switchboard panels to regulate the loading of generators or transformers, the resistance thermometer method is generally to be preferred to any thermocouple method for the following reasons:

*We are discussing this more fully under Group III papers.

1. Direct readings obtained without manipulation.
2. Actual temperature indicated instead of temperature rise.
3. Standard switchboard D'Arsonval voltmeters used instead of galvometer.

Direct readings are obtained by connecting the voltmeter according to the Wheatstone-bridge method, three arms of which being permanent resistors of zero temperature coefficient and the fourth being a search coil, wound preferably with copper. Direct current of fairly constant voltage is applied and a standard switchboard type voltmeter used in place of the usual galvanometer.

With this method, a variation of the supply voltage will cause slight errors in the indications at certain points of the scale. This can be minimized by calibrating the voltmeter with its zero torque point at the critical temperature where extreme accuracy is most desired. Thus, at this point indications would be independent of the applied voltage. At other points, there would be a slight error depending upon the variation from the zero torque point on the scale and on the variation from normal voltage. The accuracy is sufficient for all practical operating purposes but probably is not of a high enough order for testing or research work.

A notable application of this form of temperature indicator is on the N. Y. N. H. and H. single-phase locomotives, the indicators being located in the cab, directly in front of the driver's seat.

C. Fortescue (communicated after adjournment): The paper of Messrs. Johannesen and Wade calls attention to a feature of temperature determination of transformers which has always been a source of contention between the representative of the purchaser and the manufacturer. I refer to the determination of the correct temperature rise of oil-insulated transformers with fluctuating room temperature.

According to test results obtained by the authors, there is a lag of the temperature of the oil and consequently of the temperature of the coils behind the temperature of the room. It is shown that by the use of an idle unit of the same design, a base temperature is obtained from which to measure the correct rise of temperature. The temperature of the winding of the idle transformer may be used as a basis from which to measure the true temperature rise of the coils of the working transformer.

All these results may be deduced from purely theoretical considerations; thus assuming constant emissivity of the case with varying temperatures, let

θ_1 = room temperature.
θ_2 = average temperature of oil of hot transformer.
θ_3 = average temperature of oil of idle transformer.
W = weight of oil in absolute units.
α = emissivity of case in absolute units.
γ = specific heat of oil.

S = area of case surface.
E = rate of dissipation of energy in case in absolute units.
We have therefore
Heat dissipated from case $= \alpha S (\theta_2 - \theta_1)$
Heat retained in oil $= E - \alpha S (\theta_2 - \theta_1)$
and therefore

$$\frac{d\,\theta_2}{dt} = \frac{E - \alpha S (\theta_2 - \theta_1)}{\gamma W}$$

or

$$\gamma W \frac{d\,\theta_2}{dt} + \alpha S \theta_2 = E + \alpha S \theta_1 \qquad (1)$$

Consider a periodic value of θ_1 and for simplicity let us assume it to be of the form

$$\theta_1 = \theta_0 + \theta \cos c\, t \qquad (2)$$

Then the solution of (1) gives us

$$\theta_2 = \frac{E}{\alpha S} + \theta_0 + \frac{\alpha S \theta}{\sqrt{\alpha^2 S^2 + c^2 \gamma^2 W^2}} \cos (c t - \varphi)$$

$$- \left(\frac{E}{\alpha S} + \theta_0 + \frac{\alpha S \theta}{\sqrt{\alpha^2 S^2 + c^2 \gamma^2 W^2}} \cos \varphi \right) e^{-\frac{\alpha S}{W \gamma} t} \qquad (3)$$

where $\tan \varphi = \dfrac{c \gamma W}{\alpha S}$

The last term vanishes when t becomes infinite and at the end of a long period its effect is negligible.

The temperature condition of the idle unit is obtained by making $E = 0$ in (3). This gives

$$\theta_3 = \theta_0 + \frac{\alpha S \theta}{\sqrt{\alpha^2 S^2 + c^2 \gamma^2 W^2}} \cos (c\, t - \varphi)$$

$$+ \left(\theta_0 + \frac{\alpha S \theta}{\sqrt{\alpha^2 S^2 + c^2 \gamma^2 W^2}} \cos \varphi \right) e^{-\frac{\alpha S}{W \gamma} t} \qquad (4)$$

Subtracting this from θ_2 we have

$$(\theta_2 - \theta_3) = \frac{E}{\alpha S} \left(1 - e^{-\frac{\alpha S}{W \gamma} t} \right) \qquad (5)$$

which is also the solution for temperature rise of the transformer above a constant room temperature. It is therefore evident that the rise of the hot transformer above the idle transformer is the same as the temperature rise of the transformer under conditions of constant room temperature at every point of the temperature curve.

In addition to corroborating the results obtained by the authors, the theoretical solution clears up one point they seem to be not altogether sure of, namely the proper value of room temperature on which to base the temperature rise of the transformer when no idle transformer is available. The problem is in the case of irregular variations to a certain extent indeterminate, but the correct value may be obtained by a method of trial and error in the following manner.

Take two points on the curve of air temperature representing as nearly as possible to the eye a complete periodic variation. Obtain the average value of the room temperature between these points and draw a straight line parallel to the datum line and at a distance from it equal to the value obtained. This will intersect the curve of room temperature at three points which include between them a portion of the room temperature curve which approximates a true harmonic cycle. Proceeding as before a second average is obtained between the points on the curve indicated by the first average; repeat the process until there is no change in the position of the points obtained by the line parallel to the datum line. The last average temperature will be the true base temperature of the room between these points and the correct rise may be obtained by taking the average temperature of the oil and coils between these points and subtracting the average room temperature as obtained above.

This value of room temperature is the quantity θ_0 used in the above discussions in (**3**). The integral of the periodic portion through a complete cycle vanishes, so that if t be sufficiently large we have,

$$(\theta_2 - \theta_0) = \frac{E}{\alpha S}$$

which is the temperature that would be obtained in the transformer with a constant room temperature equal to θ_0.

H. L. Wallau (communicated after adjournment): Table 1, given in Messrs. Atkinson and Fisher's paper on "Rating of Cables" was most astonishing to the writer and does not agree with his experience.

Records kept during the last ten years on a 1,000,000-cir. mil cable operating at from 115 to 150 volts to ground, show that with the exception of the winter of 1906, when the load on this cable did not exceed 700 amperes, it has been subjected each year for a period of two to three months from 1902 to 1913 to an overload of 30 per cent for three hours, five days a week, and 20

per cent for six to seven hours one day a week, and has carried between 80 and 100 per cent of its normal load for four to five hours before the overload came on.

This feeder has been in continuous service all of the time and has given no trouble. Its insulation consists of 4/32 in. (3.1 mm.) oiled paper and it has an 1/8 in. (3.1 mm.) lead jacket. The performance of this cable is not phenomenal, practically all of the low tension cables on the system giving like results. These cables pass through subways containing twenty to forty similar cables operating at similar loads.

A 2200-volt, No. 4/0, B. & S. three-conductor cable 3/32 by 3/32 in. (2.3 by 2.3 mm.) insulation carried continuously for 10 hours a day an overload of 25 per cent and for 14 hours a day a load of 20 per cent of normal, for over six months, with but one break-down during the period, and is still operating with a maximum load of 75 per cent of normal.

More caution should be exercised in overloading high voltage cables since the potential gradient through the insulation is not a straight line but very steep next to the conductor.

A. Herz (communicated after adjournment): I agree with Mr. Johannesen and Mr. Wade in their policy of using a mass of iron, copper and oil as reference standard for room temperatures in making heat runs on oil-insulated transformers. Such reference units should not have larger heat storage capacity than that which would follow changes in room temperatures in the course of about one hour. I mean that the time lag between a change of room temperature and that same temperature shown by means of the above temperature standard should be in the order of one hour. A small transformer would conform to this.

It has been the practise for some time in the past when specifications are drawn up for the purchase of transformers, to specify that the transformers are to be subjected to a double voltage run at suitable frequency as one of the acceptance tests. I think there is no test which gives a person as much certainty of the condition of the insulation between individual turns in the windings and also between the separate parts of windings which are subjected to potential differences in normal operation as such an overvoltage run. I have elaborated somewhat on this and used a similar scheme in the purchase and testing of generators, in so far that a certain per cent overvoltage operation be part of the acceptance test, this to be obtained by excess excitation or by overspeed run (not to exceed 15 per cent), or a combination of both. I have found no trouble in obtaining as high as 40 per cent excess voltage by such means and after such test in combination with the regular breakdown test I have felt reasonably safe in turning such apparatus over for regular operation. I have also on several occasions discovered defective insulation and coils by these means. The mere fact of apply-

ing the usual test voltages between the windings of apparatus and the ground does not put any potential difference between adjacent coils or between the individual turns or insulated joints made in assembling the winding. A generator for instance could not be tested for breakdown between phases or between coils unless all the individual coils were disconnected from each other at the time of such test, which is usually a practical impossibility. Even then the individual turns would not be subjected to any excess voltage. I would therefore recommend that a paragraph be incorporated in the Standardization Rules to require all apparatus to be operated at excess voltage for a period of one minute. In the case of generators which are usually not subjected to excess potential stresses, such as line surges, an overvoltage run of 40 or 50 per cent would be reasonable; in transformers, as is now the practise, an overvoltage run of one hundred per cent would be reasonable; in other apparatus such excess voltages as would be deemed best by the committee.

Core temperatures, when read by a thermometer, should have such thermometer bulbs in contact with the core in such a way that there is practically no radiation from the heat conducting medium connecting the bulb with the core. The usual method of using putty is such that the large areas of putty exposed to the air put the thermometer bulb in the presence of a medium cooler than the core, at least on one side. I think due attention should be paid to this, and whenever putty is used it be covered again by heat insulating mediums, such as cotton waste. I have obtained higher temperature than those obtained by the usual method, when covering a thermometer bulb with metal foil, this covered with a small amount of putty, and then the whole covered with a layer of waste. This high temperature was not due to local rise, because in the cases I have in mind, the area occupied by the thermometer covered as above, was but a fractional part of one per cent of the total area exposed to radiation.

Whenever exploring coils or thermocouples are used in proximity to coils within the electrical apparatus in order to measure temperature existing in proximity to such devices, such means of obtaining temperature should not be used unless suitable provisions are made, that in case of a breakdown between the coil or conductors and such devices, no injury will happen to the testing apparatus or the operator. The precautions are essential, since the insulation of the apparatus under temperature test was probably never subjected to such electrical stresses as it will be subjected to while under this test, and hence due caution must be used.

D. W. Roper (communicated after adjournment): The question of the limiting temperature of lead covered cables is one of extreme interest to all users of such cable. A careful inquiry into the records and among the men actively engaged on the work of installation and maintenance of a system whose maximum load exceeds 200,000 kw. fails to disclose a single case

of failure of a cable which could be definitely traced to overload. One case was found where a low-tension cable main had carried such heavy loads that the paper insulation was charred and brittle, but it was still in service, and the condition was discovered at the time that the services were transferred to a heavier cable. In other cases low-tension feeders have carried loads far above the loads generally considered as safe for such cables and have melted the solder in the terminal lugs and in the copper sleeves connecting the sections of cable. These cables carried these excessive loads without any apparent injury, and a careful examination of sections cut from the cable after having carried these loads, failed to disclose any perceptible difference in appearance from new cable. Our experience, therefore, appears to indicate that the temperature of low-tension, paper insulated cables is limited by other factors before we reach a temperature that will permanently injure the insulation.

With high-tension cables the behavior is somewhat different. A number of cases have occurred where cables have burned out due to local heating, as, for example, where a conduit line passed over a steam pipe, or where exhaust steam has been turned into a catch basin adjacent to a conduit line. Instances of this kind are not at all rare, and in some cases it has been necessary to re-lay a conduit line or move a steam pipe in order to avoid the frequent burnouts of the high-tension cables at such warm locations. An inquiry among a number of the larger users of high tension transmission cable shows that all of them have had such cables fail during, or immediately after, a particularly warm spell of weather and without any apparent cause.

A paper by Mr. Rayner in the July, 1912 number of the *Journal* of the Institution of Electrical Engineers, gives a clew to the cause of such burnouts, and this clause is briefly touched upon by Messrs. Atkinson and Fisher in their paper, wherein they state that "the increasing dielectric loss with increasing temperature must be considered." Mr. Rayner's investigations indicate that with all types of fibrous insulation the dielectric loss increases quite rapidly with increasing temperature. It follows, therefore, that for each kind of fibrous insulation there is a temperature which may be called the "critical temperature" at which the dielectric loss is equal to the heat loss by radiation. If, therefore, the temperature of the insulation of a high-tension cable should from any cause exceed this critical temperature, then the dielectric loss being greater than the radiation, the temperature of the insulation will continue to rise as long as the potential is applied, although the load is entirely removed. Apparently high-tension cables break down in service from this cause. The trouble does not occur on the hottest day in summer, but a day or two afterward. The cable, apparently, during the maximum load period on a hot day, reaches a temperature above the critical temperature, and then continues to increase in temperature gradually over a period of a day or two or more

until it finally breaks down. While, therefore, it may not be strictly correct to state that the cables have burned out from overload, they have failed because they were allowed to exceed the critical temperature for the particular voltage at which they were operated.

So far as is known to the writer, this limiting temperature for high-tension cables has never been determined. It probably varies with the thickness of insulation, the operating voltage and with the nature of the insulation. As near as can be judged by experience, this point is of no great consequence in cables operating at voltages under 10,000, which have the usual thickness of insulation for such voltages. The experience with cables operating at higher voltages, however, indicates that in hot weather, or where the cable is subject to heat from some external source, loads which are generally considered well within the safe capacity for such cables, will suffice to heat them beyond the limiting temperature.

It is therefore suggested that in determining the safe carrying capacity of high-tension cables, due consideration be given to the dielectric loss at the higher temperatures.

Edmund C. Stone (communicated after adjournment): It is very interesting to see how much quicker the limiting temperature is reached, and how much shorter are the periods of overload, on cables than on other kinds of electrical apparatus. The tables on pages 572–3 bring out clearly the danger to cables from even short overloads and the necessity of securing immediate relief if a cable becomes unexpectedly overloaded.

It seems to me that more information than now ordinarily obtained regarding the performance of cables would be of definite value to the users.

It is evident that other things being equal, if one make of cable would operate safely at materially higher temperatures than others, or had heat dissipating qualities that would permit it to carry a materially heavier load at the same temperature, that cable would be distinctly advantageous to use—indeed, would be worth more in cents per foot. If one cable had a materially higher dielectric loss, it would be distinctly more subject to breakdowns under emergency conditions of overload, for the larger the dielectric loss the more rapid the internal temperature rise under abnormal conditions; hence such cable would be distinctly disadvantageous to use. Likewise the charging current would become important if excessively large, and if any of these characteristics should change materially, it would be of great importance to the operating man to know of these changes, in order that he might adjust his conditions to suit them. For example, formerly the exciting current of a transformer could not be excessive, but recently, through the use of different qualities of steel, it has become an important factor, and it is probable that a large number of transformers have been bought with entire ignorance of the excessive exciting cur-

rent that is present, to cause a reduction in the power factors of the system.

C. P. Randolph (by letter): Mr. Williamson brings out clearly several important points affecting the calculations of the temperature drop in electrical machines. I wish to emphasize some of these. It is absolutely essential in order to make accurate calculations of this kind that there be no space filled with air between the different kinds of insulation. The air films play a very important part in the resistivity of electrical insulations where the heat flow is in a direction at right angles to the layers of insulation. On looking over the tables on thermal conductivity presented in Mr. Williamson's article, and also those measured by Symons and Walker, the most noticeable feature is the slight differences in the conductivity of the various materials. It is very likely that the resistivity is due chiefly to the number and thickness of the air films between the layers of mica, cloth, etc. Though the air films between layers are very thin, nevertheless they are present. The writer has found by measurement that the thermal conducivity of layers of mica 0.003 in. thick when under a pressure of five lb. per sq. in. is about 0.0024, whereas when the disks are loosely piled on each other (under a pressure of perhaps one-fourth lb. per sq. in.) the thermal conductivity is 0.00090* or about one-third of the former figure. The conductivity of a pile of mica sheets will increase with the pressure very rapidly at first, but very slowly when the pressure has passed such a value that the air films are nearly absent. This pressure is always exceeded in properly assembled coils when they are firmly imbedded in the slots, so that one should be able to calculate the temperature difference between the copper and the iron with a degree of accuracy sufficiently high for practical purposes. The temperature coefficient of the thermal conductivity of layers of mica when tightly pressed is very small, and when loosely pressed it is very high.

Problems involving the calculation of heat losses are always very complex even in carefully designed laboratory apparatus, and the calculation of the temperature at many points in a generator or motor under different operating conditions presents problems so complex that they are often practically impossible of solution. Fortunately the designer wishes to know the temperature only at the places where it is highest and often the problem can be so simplified without impairing the accuracy that the necessary calculations are comparatively simple. Mr. Williamson shows clearly how to handle one of a number of such problems that arise. There are no engineering problems that require the exercise of "good judgment" to arrive at results of value, so much as those involving the flow of heat. Practically every problem requires that some assumptions be made, as otherwise the calculation would be too complex to handle. The simplifying

*The thermal conductivity is given in watts per degree centigrade per inch cube.

assumptions may allow problems that at first appear to be impossible of solution finally to be solved accurately and easily. At the same time these assumptions may lead easily to results 100 per cent in error, if "good judgment" is not exercised. Experience in dealing with problems of heat flow is necessary to obtain correct results. When a problem is so complex that one cannot be sure of the accuracy of the calculations the result may be merely used to locate places of high temperature. Then temperature coils may be inserted at these points to determine the actual temperatures.

The designing engineer should have at his command accurate data as to the life at different temperatures of the various insulations, so that each material can be used under the temperature conditions to which it is most suited. Data on this point are needed now more than data on thermal resistivity. Such data are very difficult to determine experimentally, but without them we must use relatively high—and therefore expensive—factors of safety.

It is the actual temperature of the insulation, and not the temperature rise which limits the out-put of a machine, as has been brought out in several papers presented at this meeting of the Institute. This depends no tonly on the temperature of the surroundings, but also on the conductivity of the insulating materials, iron, etc., and on the surface properties of the machine. For instance, to test a machine before it is painted may lead to erroneous results. Painting usually increases the emissivity, thereby making the machine run cooler than previously. Reliable data on this point are very meager, but the writer is at present carrying out some experiments to clear it up.

E. D. Edmonston (by letter): Messrs. Atkinson and Fisher have given engineers and users of cables much valuable and needed information. There has been a dearth of information on underground electric cables, and for much of the published data we have had in the past, we are indebted to Mr. Fisher and his company.

We have been given the maximum temperature limits of safe practise in working cables, but we are not as yet in possession of enough data to predete mine fairly accurately the current rating of an electric cable for service underground in various conduit formations, in various soils, under varying conditions.

The formulas given, as stated, are based upon experiments on the rise in temperature of cables in free air, whereas most of our lead covered cables for power and lighting service are placed underground in conduit constructions where there is little appreciable circulation of air through the ducts.

From the formulas given we may compute the temperature rise of copper above lead, and the rise of lead above immediate surroundings; but in the rise of temperature of surroundings due to the presence of other cables and the nature of the surroundings, we have only meagre and limited data available on which to base

a guess in many of our calculations. Yet, as the paper states, heating and current rating of any given cable may be reduced to a half or a small fraction of its normal rating due to the extreme variability of the external conditions. For underground cable work, therefore, to make the fullest use of the valuable information given in this paper, we should endeavor to obtain more information than has been published concerning the conduction of heat by the earth, when conduit lines are laid in clay, loam, sandy soil, etc., both when the soil is damp and when dry. In the usual subway construction, with manhole spacings of 200, 300 or 400 ft. I believe that there is little dissipation of the heat generated in cables through possible circulation of air in conduits, but I would like to obtain the views of others on this matter.

Turning for a few moments from the subject of cable heating from the conductors, to the heating of cables from without, you may be interested in some findings in Baltimore where we have nearly a half-million feet of several different makes of 13200-volt transmission cables in the lighting and power company's service, installed over a period of about nine years. Some of these cables which had been in regular service for some years began to cause us trouble for the first time last summer. In a conduit line where we had twelve transmission cables, we had a cable breakdown between manholes in one section. This was followed about a week later by the breaking down of another cable at the same point in the conduit line, but of course in another tile duct. A week or so later another cable broke down at the same point in the conduit line, and so on until we had lost five cables. The cables in question were three-conductor, 4/0 B. & S. gauge, 6/32 in. by 6/32 in. paper by 5/32 in. lead sheath; and the breakdowns occurred between conductors. A short time after the initial breakdown, we had a breakdown of a cable between manholes in another section of the conduit line, which was followed after short intervals of time by four additional breakdowns at about the same point in the conduit line in nearby ducts. We dug around and exposed the conduit line at the points of trouble, examined the conduit construction, examined the adjacent cables for signs of electrolysis, and found nothing unusual in the nature of the soil. All of the cables have been working well under normal rating, and the maximum temperature we were able to get between manholes in the duct line was about 52 deg. cent. by recording thermometers. We sought to find some electrical phenomena to account for the trouble, and failing in this I took our troubles to our chemists. Moisture was found to exist in quite considerable quantities in the paper insulation. Many samples of cable, and also some new cable, were carefully taken, from all of which we were able to distill (using a temperature under 120 deg. cent. with a vacuum of approximately 26 in.) from 1 to 2 grams of water per 5-in. lengths, which is equivalent to about 1 to 2 ounces of water per 10-ft. length of cable. We cannot account for the cause

of initial breakdowns mentioned; but we feel satisfied that the succeeding breakdowns at the same points in the conduit line were caused by the localized heat from the first short-circuit vaporizing the moisture held by capillarity in the paper insulation of the adjacent cables, which vapor, driven back in the cables from the hottest point, distilled in globules of water at a nearby point where the cable was sufficiently cool to condense the vapor; and these globules of water so formed, did the rest after a period of time. All of the cables affected were ordered under the American Standard General Cable Specifications covering paper insulated lead covered cables prepared by the Paper Insulated Power Cable Engineers' Association, were tested at factory and after installation, and complied fully with the specifications. Replacement of the damaged sections of cable by the manufacturer, under a five year guarantee, does not compensate for the loss of prestige and service due to the interruptions caused by the cable breakdowns.

The point I wish to make, is that we have not a standard cable specification which will adequately protect the purchasers and users of cables, especially high-tension cables for under ground service. I have appealed to three of the large cable manufacturers to tell me the limitations of moisture which they could assure in a specified make-up of cable; but in each case their answers have given me to believe that they had little knowledge of how complete their vacuum process was in extracting the moisture from the paper before applying the compound and sheathing; and this has led me to draw up my own specifications for the limitations of moisture.

Mr. Fisher, in a previous paper before the Institute, stated that it was to be regretted that the manufacturers and operators of electric wires and cables in this country did not draw up a reasonable set of specifications, because it would simplify matters for consulting engineers, operating companies and manufacturers. We are all striving for standardization, and I beg to suggest that the work of formulating an adequate set of cable specifications could well be taken up by the Institute and would bear good fruit for both the users of cable and the manufacturers.

In some of the big cities, millions upon millions of dollars are invested in undergound electric cables. The valuation of the underground cables in our little power and lighting system in Baltimore totals an amount in the seven figures, and approximates the total cost of all the electrical equipment in our stations; yet with some lighting companies where greater portions of their distributing systems are underground, the cost of underground cables probably exceeds the total investment in all station equipment. With such amounts involved, the operating companies are naturally most desirous of obtaining cables of the best design and construction at a fair cost, and knowing of how to work those cables to the best advantage underground in properly designed conduit construction. Reports

by a number of the large lighting companies made last year to the National Electric Light Association Committee on Underground Construction, give evidence concerning high-tension cable breakdowns which indicates that there is yet much to be desired in the make-up of, at least, high-tension cables; which weaknesses in construction have not been shown by the initial tests that have heretofore been customary to apply. Many cable users say, with much logic, "leave the make-up of cables to the manufacturer," but on high-tension paper cables the manufacturers appear not all in accord. True, many of them appear to use much the same cable compound, principally resin oil, under different trade names. The papers used appear not to be very different in character, though the quality may differ somewhat; but the thickness of the paper and the tightness of the wrapping varies considerably for high-tension cables. Some manufacturers recommend a loose wrapped high-tension cable, others, a tightly wrapped cable. Each has certain advantages, but on account of the paper costing considerably more than the compound used, is there a temptation for the manufacturers to use a loose wrapping, though the tight wrapping may be desirable? The Institute affords a common ground for cable manufacturing engineers, and engineers of cable users, to get together in an endeavor to formulate more adequate specifications than we have yet had, and give to the profession at large recommendations which would be of tremendous value and in line with standardization. I venture to hope that an Institute Committee will take up this work.

NOTES ON OIL CIRCUIT BREAKERS FOR LARGE POWERS AND HIGH POTENTIALS

BY

K. C. RANDALL

Presented under the auspices of the

Papers Committee for the Pacific Coast Convention

F. D. NIMS, Chairman.

D. P. ROBERTS. W. W. FRASER.

1885

NOTES ON OIL CIRCUIT BREAKERS FOR LARGE POWERS AND HIGH POTENTIALS

BY K. C. RANDALL

Abstract of Paper

The paper gives a brief outline of some of the important developments in oil circuit breakers which have taken place within the last two or three years. Ideal conditions require that the current should not re-establish itself after passing the first zero value following the opening of the contacts, and this emphasizes the value of high opening speed in a circuit breaker. Breakers have been designed in which resistances were introduced to limit the current to a value readily ruptured, but as this principle is difficult of accomplishment, reactance has been successfully substituted for resistance. Reactance breakers have two sets of contacts, the main set which carries the normal current, and an auxiliary set which carries the reduced current after the reactance has been introduced by the opening of the main contacts. Breakers for any power and voltage, with all the usual methods of operation are now available.

A paper to be presented at the 285th Meeting of the American Institute of Electrical Engineers, Vancouver, B. C., Sept. 11, 1913.

(Subject to final revision for the Transactions.)

NOTES ON OIL CIRCUIT BREAKERS FOR LARGE POWERS AND HIGH POTENTIALS

BY K. C. RANDALL

The purpose of this paper is to outline briefly the latest developments in oil circuit breakers for the largest powers and highest potentials.

The rapid increase in powers to be handled by switching apparatus in keeping step with the growth of generating and transforming apparatus has developed the need of oil breakers with breaking capacities much in excess of what has previously been obtainable. The former designs are now in many instances utterly inadequate.

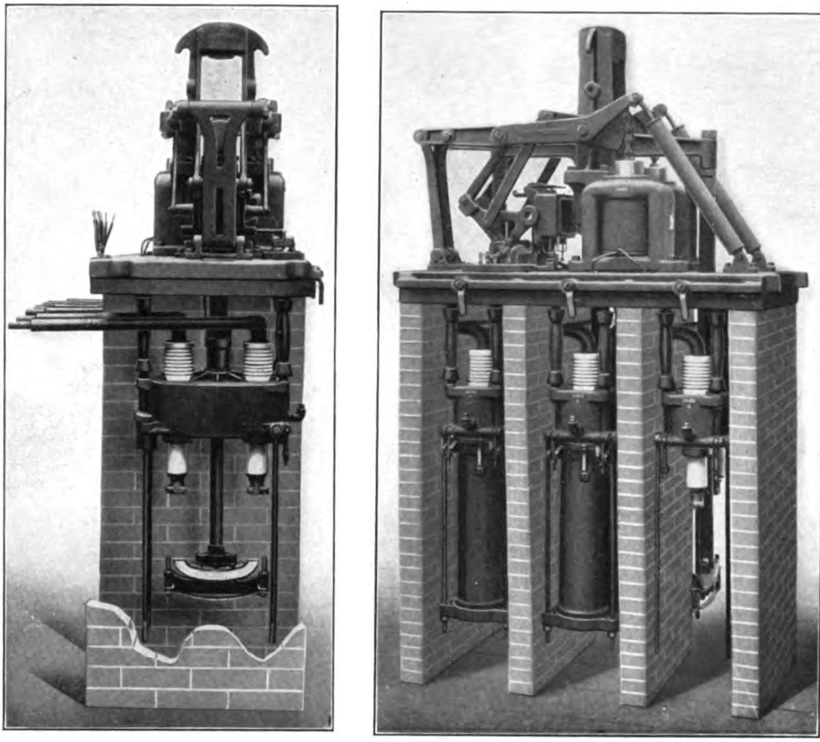
As an evidence of the common appreciation of the difficulty in obtaining competent circuit breakers, may be cited the tendency to employ current-limiting reactances on heavily powered systems.

Tests for obtaining data on which high-power breakers may be thoroughly tried out are only practicable on large power plants, which are rarely available for this purpose. It requires much courage and deep interest for an operator to hazard his machinery and service for obtaining data that, usually, will be used by the manufacturer rather than by the operator, although the latter may be the particular beneficiary. As a result, much circuit breaker development is based on field experience and observation rather than on logical consecutive tests usual with other apparatus. However, a number of important tests have been made within a few years, but these have only been at moderate voltages. So far as the writer is aware, no extensive high-potential tests have ever been conducted on oil circuit breakers.

The salient features of a modern breaker for a large plant (Fig. 1) are simplicity, accessibility, adequate rupturing capacity —which embodies strong tank construction, good head of oil over contacts, liberal expansion chamber over oil provided with vent, accelerated operation and good contacts with readily renewable arcing tips. The oscillogram (Fig. 2) well illustrates the operation of such a breaker. The speed of rupture ($\frac{1}{2}$ cycle) is clearly shown by the smooth current curve until the last half-cycle when the voltage across the arc first appears and immediately becomes normal. This operation at 12,000 volts, 25 cycles, 12,000 amperes, was not manifested externally even by an appreciable show of smoke from the vents.

Considering the gradual increase in the rating of breakers it is noted that, as the current carrying capacity grows, the weight of the current-carrying parts becomes greater, and also the mechanism for operating these parts. In other words, the inertia of the breaker is increased and, also, the friction of the mechanism. Mechanical devices are available for accelerating any mass, as may be necessary, but this in turn demands means for bringing the accelerated mass quickly to rest at the end of the stroke. All of this becomes more difficult as the need for higher rates of opening, corresponding to increased voltages, and greater mass, corresponding to increased current-carrying capacities, are to be dealt with.

It is worth while to analyze briefly the characteristics of the ideal breaker, considered solely as a current-rupturing device, namely, neglecting its current-carrying function and other mechanical considerations. Ideally, the current of the circuit should not reestablish itself after passing the first zero value following the separation of the contacts. This means that in 60-cycle service not more than 1/120 (0.0083) of a second should elapse before the contacts have sufficiently separated to make the reestablishment of current impossible. With such a breaker the minimum energy will be dissipated between the contacts, and consequently with the least possibility of failure. In contrast to this, the more slowly operating breaker may allow the current to reestablish itself consecutively several times after the first separation of the contacts has occurred, and in this way may dissipate much energy, which is usually manifested in a mild way by smoke issuing from the oil tanks, and in a violent way by the bursting of the tanks, tearing them from their fastenings, or even quite complete destruction of the breaker.



[RANDALL]

FIG. 1.—A MODERN CELL STRUCTURE OIL BREAKER.

For potentials up to 25,000 volts and systems of 40,000 to 120,000 kv-a., according to method of operation.

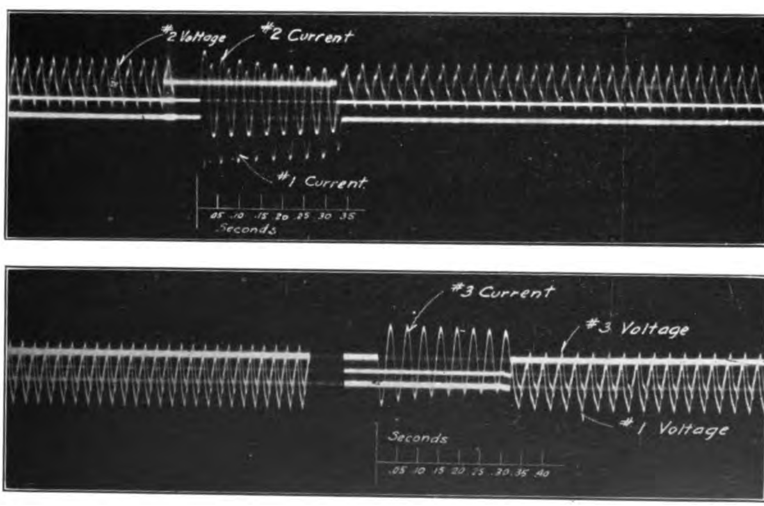


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FIG. 2.—OSCILLOGRAMS SHOWING RUPTURE OF HEAVY POWER CIRCUIT BY BREAKER ILLUSTRATED IN FIG. 1, 12,000 VOLTS, 12,000 AMPERES.

Note that current is ruptured in ½-cycle after establishment of arc voltage, which itself endures but ½-cycle and then becomes normal

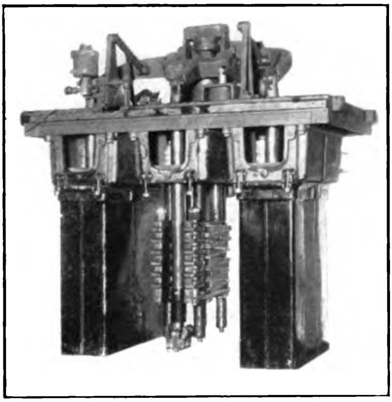

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FIG. 3.—AN EARLY SUCCESSFUL FORM OF THE RESISTANCE TYPE, PNEUMATICALLY OPERATED OIL CIRCUIT BREAKER.

Note seven contacts which are passed over by contact fingers at end of operating rod, thus introducing the resistance by six steps into the circuit.

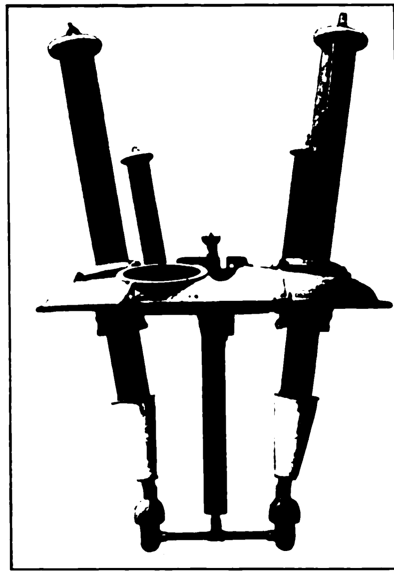

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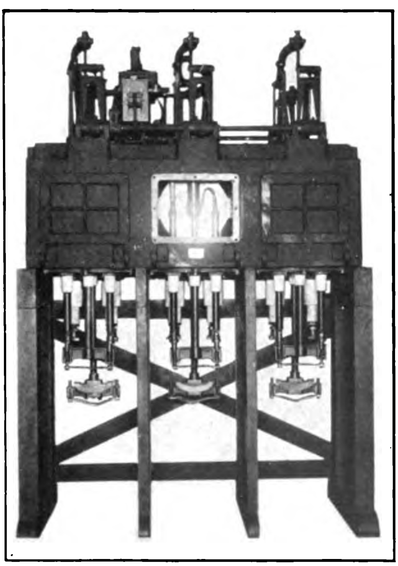
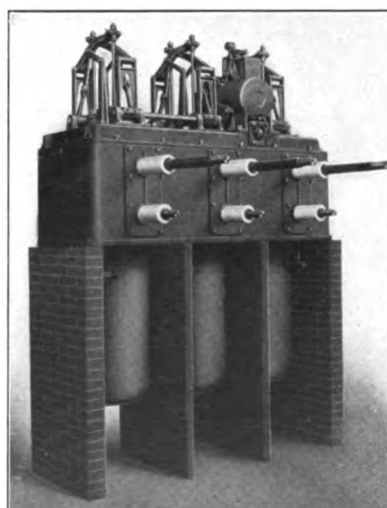
FIG. 8.—INTERNAL VIEW OF SINGLE-POLE UNIT OF HIGH-ACCELERATION BREAKER

This design is especially adapted to high and extra high potentials. Tested to 420,000 volts.





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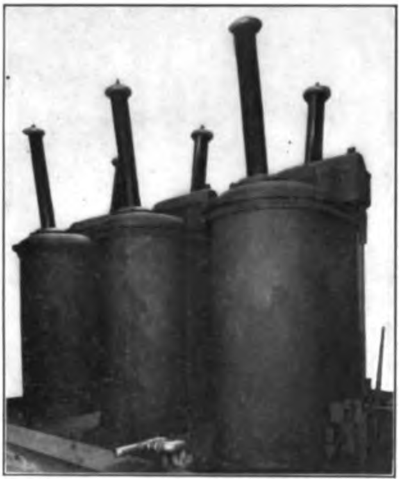
FIGS. 6 AND 7.—REACTANCE BREAKER, RATING 1200 AMPERES, 15,000 VOLTS, FOR 200,000-H.P. PLANT.

Illustrates type built for service from 5000 to 25,000 volts. Reactance coils are exposed by removal of cover of middle pole.



[RANDALL]

FIG. 9.—VIEW OF ASSEMBLED THREE POLES OF HIGH-ACCELERATION BREAKER.

Interior of one pole shown in Fig. 8. Approximate dimensions: height, 16 ft.; floor space, 24 by 8 ft.

[RANDALL]

FIG. 12.—A 110,000-VOLT, 600-AMPERE REACTANCE BREAKER.

Operating mechanism for either el ctrical or hand. Over-all floor space about 14 ft. by 5 ft. 8 in.; height, 12 ft. 6 in.

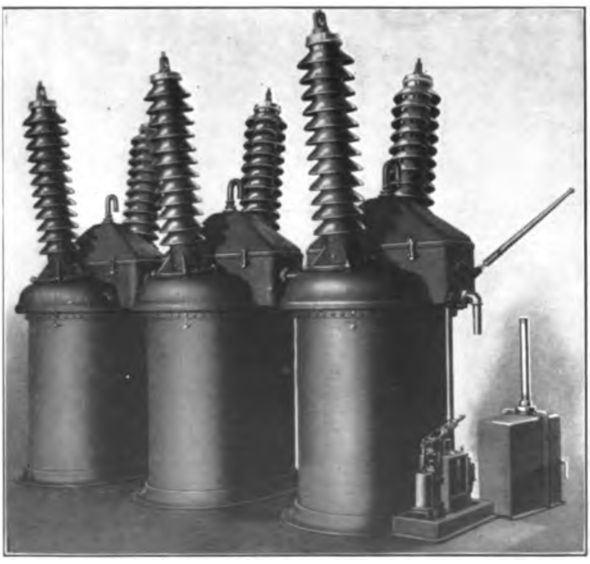


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FIG. 11—AN OUTDOOR, 110,000-VOLT, 300-AMPERE CIRCUIT BREAKER.

This illustrates a general type of design built in voltages from 40,000 to 165,000 volts.

The value of a high opening speed may be appreciated from the following analysis in which, for the sake of simplicity, assume temporarily that arcing between contacts does not influence the arc-quenching ability of the breaker. With a breaker adjustable as to speed of operation, arrange that after the contacts separate the rate of opening shall allow the current to hold for ten cycles. Readjust the breaker to hold for five cycles, for 2½ cycles, and for ½ cycle. Corresponding to each cycle, heat would be dissipated, and total amounts of heat proportionally of 10, 5, 2½ and ½ would, on an average, have been dissipated, for the current volume, voltage and length of arc were the same in each case. But the assumption that the arc gases would not affect the operation of the breaker is known to be incorrect. In fact, the presence of arc gases necessitates longer openings to rupture the currents. This, then, means that the slower the rate of opening, the greater must be the opening before rupture occurs, and this again increases the time of arcing, with corresponding dissipation of heat and probability of failure and damage. Any rate of opening faster than ½ cycle will gain nothing, as, on the average, the stored energy of the circuit may be assumed to appear as heat at the arc; hence if the arc holds only to the first zero (½ cycle), the same stored energy of the circuit will have been dissipated. However, if the current is reestablished the circuit is recharged, to be again dissipated in the arc as often as the current may pass the zero.

As a design departure intended to comply generally with the demands of a good breaker, as implied in the foregoing, the resistance breaker (Fig. 3) was developed. Briefly, the operation of this breaker, by a number of steps, introduced a resistance into the circuit sufficient to limit the current to a value readily ruptured. The fundamental idea was to reduce the enormous short-circuit currents to values which could be opened with certainty by an ordinary breaker. The principle is an excellent one but the accomplishment is difficult for several reasons, some of which are: the fundamental fact that resistance absorbs real energy, becomes heated, and in case of delayed operation of the breaker may be destroyed; the necessary contacts and insulation for such a resistance form a serious problem. There are also mechanical forces to be dealt with. The substitute for resistance in such an application is reactance, and reactance is now used for the purpose.

The general scheme of the reactance breaker differs from the

resistance breaker illustrated, in that but one step is used to introduce the whole reactance, also two sets of contacts are used: one a main heavy set of contacts which regularly carry the load current, and the second an auxiliary set which only carry the reduced current after the main contacts have opened and thus

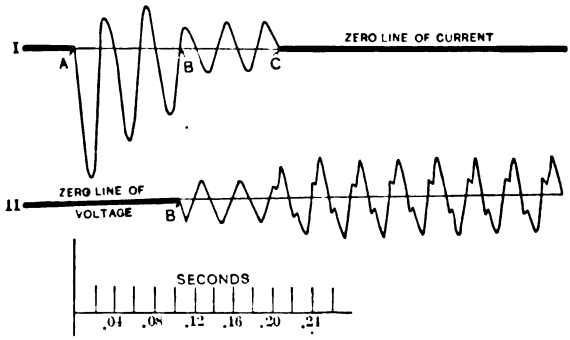

FIG. 4.—OSCILLOGRAM ILLUSTRATING OPERATION OF REACTANCE BREAKER TAKEN ON A 12,000-VOLT SYSTEM.

Maximum current of approximately 16,000 amperes reduced (at "B") to approximately 3000 amperes by the introduction of reactance.

introduced the reactance into the circuit. The auxiliary contacts rupture the final current when they separate and are also first to make contact when closing the breaker.

The design of a suitable reactance coil involves a knowledge of the maximum current which the breaker will be required to

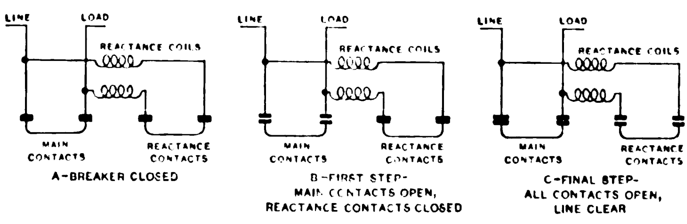

FIG. 5.—CONNECTIONS ILLUSTRATING OPERATION OF REACTANCE BREAKER ILLUSTRATED BY OSCILLOGRAM, FIG. 4.

rupture, the potential and frequency of the circuit, and the time which the reactance coil may be required to carry the maximum short-circuit current which the system can deliver through the coil. A coil properly designed according to these data will limit the currents to desirable values and carry, with a good margin,

the maximum short-circuit currents for periods which will never be exceeded in the normal operation of the breaker. The size of conductor in such reactance coils is small, compared with that normally required for the currents involved, because of the short times during which the reactance is in service.

Analysis of test results and theoretical considerations indicate that the reactance breaker properly designed is adapted to any possible power and class of service. This is due to the readiness with which the current-limiting reactance can be introduced into

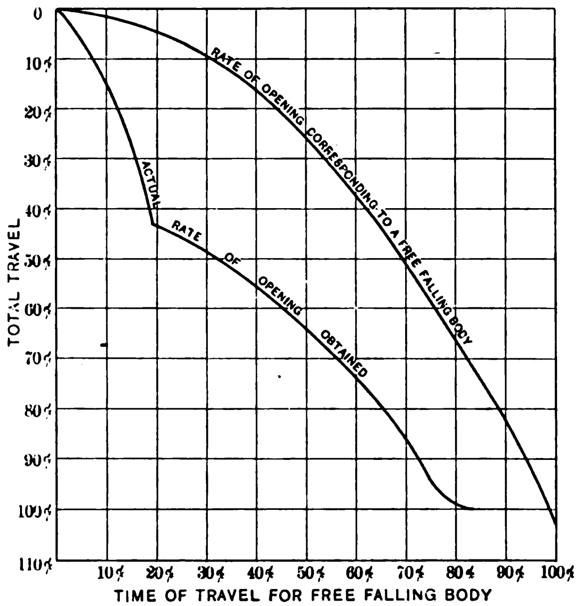

FIG. 10.—CURVE SHOWING RATE OF OPENING HIGH-ACCELERATION BREAKER.

NOTE: 40 per cent of travel, which is required to rupture heavy load, is approximately four times as rapid as that of a free falling body.

the circuits carrying enormous currents, which are thereby reduced to values easily within the rupturing capacity of the breaker.

The resistance breakers have the apparent requisite of absorbing true energy. The reactance breaker does not, and it was at first feared that on some systems the reactance breaker might cause resonance, but a very careful analysis covering a very wide range of conditions indicates that the probability of resonance from the use of reactance is so slight that it may be

called nil. The oscillogram, Fig. 4, and the diagram, Fig. 5, illustrate the operation of a reactance breaker. These breakers have already been built for a number of voltages ranging from 15,000 to 110,000 volts, as illustrated in Figs. 6, 7 and 12, and may obviously be built to meet any requirements. In general, they are to be recommended for circuits where plain breakers are no longer adequate, where the capacity is so close to the ultimate limit of the plain breaker that it is not desirable to take the chance, or where future extensions will require them.

Referring again to the ideal breaker for heavy powers with its high rate of operation, the seriousness of this requirement is more impressive at the extra high potentials, for under these conditions the necessary dimensions required for insulation purposes make rapid operation a difficult matter, even though the current volume may not be large. Practically all high-potential oil breakers built up to the present time have been slower in opening than a free falling body, owing to the friction in their mechanisms. An entirely new design built for heavy service at extra high potentials and having a remarkably rapid rate of operation is illustrated in Figs. 8 and 9. The desirable feature of a high rate of rupture, especially during the fore part of the stroke, is particularly worthy of note. (See Fig. 10.) Actual rupture will, except perhaps in the most extreme cases, occur in less than 40 per cent of the total stroke and at an average rate nearly four times as rapid as attained by a free falling body traveling the same distance. This breaker withstood an insulation test between terminals (open) of over 400,000 volts for a minute, and a like test (closed) between terminals and ground. An idea of the size of this unit, Fig. 9, may be obtained from the following data: height to tip of terminals, 16 feet; floor space, three poles, 24 by 18 ft.

Outdoor breakers have been available so long that it need only be said that the question of protection from the elements has had ample time for demonstration and the problem may be considered solved for all classes of service.

To summarize, breakers for moderate powers and voltages have been well standardized as to design and rupturing capacity. Broadly, the whole subject has developed exceedingly in the past two or three years. Now each individual problem can be definitely and economically prescribed for, and breakers for any power and voltage, indoor and outdoor, are available with all the usual methods of operation, both as to closing and tripping.

TUNGSTEN LAMPS OF HIGH EFFICIENCY

I—Blackening of Tungsten Lamps and Methods of Preventing It

BY

IRVING LANGMUIR

II—Nitrogen-Filled Lamps

BY

RVING LANGMUIR and J. A. ORANGE

1893

TUNSTEN LAMPS OF HIGH-EFFICIENCY—I AND II

BY IRVING LANGMUIR AND J. A. ORANGE

Abstract of Papers

The first paper describes investigations into the cause of blackening of the bulbs of tungsten lamps and discusses methods whereby this effect is avoided and the efficiency of the lamp thereby increased. The second paper describes in detail the high-efficiency tungsten lamps which have been produced by filling the bulbs with nitrogen vapor at approximately atmospheric pressure.

The blackening of ordinary lamps has generally been considered due to the presence of residual gases which adhere to the surface of the glass or are occluded in the filament. These investigations show that of the residual gases, water vapor is the only one which causes perceptible blackening by means of a cyclic process in which the water oxidizes the filament, the oxide is volatilized and deposited on the bulb, where it is reduced to metallic tungsten and the water vapor again formed. This action, however, is shown to occur only in poorly exhausted lamps, and the real cause of blackening in well-exhausted lamps is due to evaporation of the filament alone. The methods of improving the efficiency of the tungsten lamp consist of the introduction of gas into the bulb at atmospheric pressure and changing the location of the deposits by means of convection currents in the gases so that the glass opposite the filament is not darkened.

By making use of these principles, practical tungsten lamps have been produced having a life of over 2000 hours and an average specific consumption of one-half a watt or less per candle power. A number of different types of nitrogen-filled tungsten lamps are described in detail.

A paper to be presented at the 286th Meeting of the American Institute of Electrical Engineers, New York, October 10, 1913.

TUNGSTEN LAMPS OF HIGH EFFICIENCY—I

Blackening of Tungsten Lamps and Methods of Preventing It

BY IRVING LANGMUIR

While the transformation of electrical energy into heat or even into mechanical energy has for many years been accomplished with efficiencies well above 90 per cent, the artificial production of light has been notoriously inefficient.

The first carbon incandescent lamps had efficiencies of five to six watts per mean horizontal candle, but were gradually improved over a long period of years to about 3.1 watts per candle, until finally by the use of the metallized filament an efficiency of 2.5 watts per candle was reached commercially. Since the introduction of the metallized carbon filament progress with other types of lamps has been comparatively rapid, and at the present time the most efficient commercial incandescent lamp, the lamp with a tungsten filament, has an efficiency from one to one and a quarter watts per candle in the ordinary sizes.

Notwithstanding this decided improvement, we are still far from the theoretical maximum of efficiency that would be attained if all the energy of an electric circuit were converted into visible light. Drysdale (*Proc. Roy. Soc.* 80, 19 (1908) has shown that perfect efficiency for the production of white light would be about 0.10 watts per candle, whereas with the production of a monochromatic yellow-green light, the efficiency would reach as high as 0.06 watts per candle.

The luminous efficiency of the ordinary tungsten lamp is therefore not better than about 6 to 10 per cent.

It is well known that tungsten lamps can be run at voltages much higher than their rated voltage, and that in this way ex-

tremely high efficiencies may be obtained, but that the life of lamps run under these conditions is so short that the increased cost of renewals more than offsets the saving in electrical energy. It is readily seen that the limit of the commercial efficiency of tungsten lamps is therefore not determined by the melting-point of the tungsten. In fact, if the temperature of the filament is raised to the melting-point, the efficiency for a period of a few seconds may be as high as 0.20 watts per mean horizontal candle.

The causes which have made it necessary to operate tungsten lamps at such relatively low efficiencies as one watt per candle have been little understood. It seemed, therefore, that an investigation of the phenomena occurring in tungsten lamps, carried out with a view of reaching a clear understanding of the causes of the failure of the lamps, might possibly open the way to the discovery of methods by which the efficiency could be greatly improved.

The present paper is a description of some experimental and theoretical work, extending over a period of many years, which has now resulted in the production of a new type of tungsten lamp; a lamp which will give a life of more than 1000 hours, at an efficiency in the neighborhood of 0.50 watt per candle.

INVESTIGATION OF CAUSE OF FAILURE OF ORDINARY TUNGSTEN LAMPS

Ordinary tungsten lamps fail, in general, in one of two ways; namely, either by breakage of the filaments, or by blackening of the bulb. In ordinary practise the useful life of the lamp is considered to be the time which the lamp burns before its candle-power has fallen to 80 per cent of its original value, or until the filament breaks, in case this occurs while the candle power is still above 80 per cent.

The breakage of the filament was a very serious factor in the early tungsten lamps, as the filament material was extremely brittle. This difficulty has now been overcome by the production of ductile tungsten wire* and by better methods of mounting the wire in the bulbs, so that lamps can now be made which are so strong that a blow is more likely to break the bulb than the filament.

The life of tungsten lamps is therefore at present practically determined by the rate at which the candle power decreases. The main cause of this decrease is evident by mere inspection

*Coolidge, Trans. A. I. E. E. Vol. 29, p. 961, (1910)
Fink, Trans. Amer. Electrochemical Soc. 17, 229, (1910).

of a lamp which has run several hundred hours. It is due simply to the blackening of the inner surface of the bulb. It is true that the candle power of the filament itself changes somewhat during its life, but this change, on the whole, is an increase in candle power, rather than a decrease. Careful measurements show that during the first few hours running there is usually a slight increase in candle power owing to some change in the surface of the filament which causes greater emissivity of light, or to a slight increase in the conductivity of the filament which leads to an increase of the current and therefore a higher filament temperature. On the other hand there is a tendency towards a lowering of the candle power during the latter part of the life owing to the decreasing diameter and consequent fall in temperature of the filament. Both these causes are insignificant in their effect, as compared with the blackening of the bulb.

The reason for the limited life of the tungsten lamps when run at an efficiency of one watt per candle, and therefore the reason that higher efficiencies could not be obtained in practise, was evidently the blackening of the bulb.

The cause of this blackening was the subject of much speculation. The prevalent opinion seemed to be that in a normally operated lamp it was due to disintegration of the filament, caused by the presence of traces of residual gas, whereas in lamps run at much more than their rated voltage it was perhaps caused by evaporation. Others, however, considered it due to leakage currents of electricity (Edison effect) across the space between the positive and negative end of the filament. It is well known that discharges through gases at low pressures, cause a marked disintegration of the cathodes. Still others were of the opinion that the blackening of the bulb was due primarily to evaporation of the filament.

In the manufacture of carbon incandescent lamps, it had been found necessary to use a relatively high vacuum, as otherwise the lamps were found to have a very short life. That is, the bulbs blackened rapidly or discharges occurred between the two ends of the filament, finally resulting in the formation of an arc which destroyed the lamp. Various attempts had been made to prevent the blackening by the introduction of gases at various pressures in the lamp. For example, Edison (U. S. Patent 274,295, March 20, 1883) proposed introducing nitrogen or cyanogen at relatively high pressures, into lamp bulbs, for the purpose of preventing the electric discharge between the positive

and the negative end of the filament. In this way he hoped to prevent blackening. These attempts, however, were completely unsuccessful, and it can be readily shown in the case of a carbon lamp, run at say 3 watts per candle and containing nitrogen at atmospheric pressure, that the filament loses weight more rapidly than when run in a vacuum at the same efficiency. Similar experiments with cyanogen, or even cyanogen mixed with nitrogen, always give lamps which, when run at 3½ watts per candle, give a much shorter life than that of similar lamps with evacuated bulbs run at the same efficiency.

At a later date, in order to account for this failure to obtain good lamps without a vacuum, the theory was advanced that the presence of a chemically inert gas in a lamp caused a rapid disintegration of the filament by a mechanical " washing," the idea presumably being that the rapid motion of the gas molecules striking against the surface of the filament caused a disintegration of the filament. The general experience of those engaged in the manufacture of lamps did not bear out this theory and it was therefore gradually superseded by others in which the disintegration of the filament was considered to be due to chemical or electrical action of residual gases, rather than to simple mechanical "washing."

In the commercial production of lamps it was found necessary at first to use mercury pumps for the exhaustion of the lamps; mechanical pumps were not good enough. Later it was found possible to obtain a sufficiently good vacuum with mechanical pumps, which by that time had been considerably improved, by introducing red phosphorus into the stems of the lamps and by volatilizing this phosphorus into the lamp just before sealing off, and at the same time heating the filament to a much higher temperature than that at which it was to run normally. It should be pointed out that not only was it necessary to use some such special method of exhaust, but in order to obtain lamps of good life, the bulbs themselves had to be heated to a high temperature during the exhaust, in order to drive off any gases condensed on the surface of the glass. It is interesting to notice that the lamp manufacturers had adopted these precautions in obtaining a high vacuum long before the necessity for them was realized by most scientific investigators engaged in work with high vacuum.

When the lamp factories began the manufacture of tungsten lamps, they found that much greater precautions were needed in the exhaustion of these lamps than had been necessary for the

ordinary carbon lamps, and many improvements in the methods of exhaustion were adopted.

Unless all this care was taken to obtain the best possible vacuum, there were striking evidences of the presence of residual gas in the lamps after they were sealed off. For example, if the normal voltage of the lamp was suddenly applied, a flash of blue glow appeared. Gradually, after a few flashes, this discharge would disappear. This was taken to indicate that the vacuum had been "cleaned up" by the discharge. A similar action of an electric discharge is known in Geissler tubes and X-ray tubes.

In carelessly exhausted lamps, the blue glow would often persist, gradually getting worse, until the lamp "arced across," destroying the filament.

The effect of a poor exhaust was thus to cause the lamps to arc across during the aging process, or to cause them to blacken prematurely.

The general factory experience thus confirmed the opinion that the blackening of the bulb was due primarily to minute traces of residual gas, or to electrical discharges within the lamp.

Much evidence had also gradually accumulated in this laboratory showing that even remarkably low pressures of gases often produced very rapid blackening of the bulbs. A brief account of the early work along these lines has been presented before this Institute by Dr. W. R. Whitney (TRANS. A. I. E. E., Vol. 31, p. 921, 1912).

Various attempts to improve the life of lamps by obtaining a better vacuum than usual, had not been very successful. This failure, however, could not be taken as proof that a better vacuum would not improve the life. In the first place, it had been found that the vacuum of a lamp gradually improved after sealing off ("clean-up" effect), the pressure finally reaching a value probably lower than that directly obtainable by any of the well known methods of exhausting. Yet even where we had pressures lower than would be indicated by the most sensitive vacuum gages, we often had clear indications that the blackening of the bulb was due to imperfect exhaust. It seemed quite possible, therefore, that there might remain, in lamps, minute traces of some gas or vapor which we had not yet learned to remove by our usual methods of exhaust. This residual gas might easily be the cause of the gradual blackening of the bulbs.

Since the pressures were too low to measure, we had no way

of definitely knowing whether one method of exhaust was better than another, so that any failure to improve the life by a new method of exhaust might simply mean that the vacuum had not been improved.

It seemed, therefore, that the question as to whether a better vacuum would give a better lamp could only be settled by a direct investigation of the cause of the blackening.

Two lines of attack were decided upon:

1. Study of the sources of gas within a lamp.
2. Effects produced in lamps by various gases.

To facilitate this work, an elaborate piece of vacuum apparatus was built consisting of an improved form of Töpler (mercury) pump, a sensitive McLeod gage and a vacuum oven in which lamps could be heated and exhausted without being subjected to atmospheric pressure from without. Provision was made for the introduction at will of small quantities of any gas to the lamp. Special apparatus was devised by which gas analyses could be made with extremely small quantities of gas evolved within the lamp. For example, it is possible with this apparatus to make a quantitative chemical analysis of a single cubic millimeter of gas and determine the following constituents: oxygen, nitrogen, hydrogen, carbon dioxide, carbon monoxide and argon.*

Sources of Gas Within the Lamp

There are four sources of gas within the lamp bulb: first, residual gas left by evacuation; second, gas given off by the filament; third, gas from the lead-in wires or the anchors; and fourth, the gas given off by the glass.

1. *Residual Gas.* The mechanical pumps ordinarily used in exhausting lamps produce a vacuum of about 0.001 mm., according to the McLeod gage. This is probably about the pressure of the non condensible gases left in the lamp. Besides this, however, there must be some water vapor and oil vapor, and if the filament has been lighted during the exhaust, as is usually the case, there will be some carbon monoxide, carbon dioxide, and hydrogen produced by the action of the filament on the vapors. Probably most of these gases are nearly completely removed, or precipitated on the walls of the bulb, by the clean-up that occurs when the phosphorus is volatilized into the lamp and a

*For a brief description of this apparatus and the methods of analysis employed, see *Journal American Chemical Society*, Vol 34, 1912, pp. 1310 and 1313.

blue glow made to occur. The final pressure, just after sealing off, is usually in the neighborhood of 0.001 mm. or less.

2. *Gas from the Filament.* The prevalent opinion, as expressed generally in scientific literature, is that metals when heated to very high temperature in vacuum, evolve very large quantities of gas. For example, in a recent article, Prof. J. J. Thomson (Nature, 91, p. 335, 1913) says: "Belloc, who has recently published (*Ann. de Chimie et de Physique* (8) 18, p. 569) some interesting experiments on this subject, after spending about six months in a fruitless attempt to get a piece of iron in a state in which it would no longer give off gas when heated, came to the conclusion that, for practical purposes, a piece of iron must be regarded as an inexhaustible reservoir of gas." Thomson's own experience is quite similar.

That the effect of the presence of gas in the metal is considered of importance in connection with the disintegration, is evident from the following quotations from J. J. Thomson's book on "Conduction of Electricity Through Gases" (1906 edition). On page 215, he says: "The facts just mentioned suggest that the gas absorbed by the platinum and slowly given off when heated plays an important part in the carriage of the electricity from the wire."—"The emission of absorbed gas from the platinum is, however, according to Berliner (*Wied. Ann.* 33, p. 289, 1888), closely connected with the disintegration of the platinum wire which takes place when the wire is kept glowing and which is made evident by a deposit of platinum or platinum oxide on the walls of the tube and a diminution in the weight of the hot wire: the carriers of the electricity might thus be the dust or vapor of platinum escaping from the wire." Then, on page 216: "There is thus a close similarity between the laws of disintegration of the wire and those of the leak of positive electricity from it."

On page 550, in speaking of the gases given out by the cathodes of vacuum discharge tubes, he says, in discussing some work of Skinner (*Phys. Rev.* 21, p.1, 1905): "The amount of hydrogen that can be got out of a cathode in this way is very large; thus, from a silver electrode 0.15 cu. cm. in volume, Skinner obtained about 2 cu. cm. of hydrogen at atmospheric pressure, without any indication that the supply was in any way exhausted."

The first few experiments (see *Jour. Amer. Chem. Soc.* 35, 105, 1912) on the gases evolved from the filament of a tungsten

lamp also seemed to show the presence of inexhaustible supplies of gas within the filament. Later work proved, however, that this gas was not actually evolved from the filament, but was produced from the decomposition by the filament of water vapor or hydrocarbon vapors present at extremely low pressure in the bulbs. It was finally found that with small filaments, such as are used in lamps, the gas evolved by heating is not more than from three to ten times the volume of the filament. By thoroughly cleaning the surface of the wire before heating, the amount of gas is usually not over half as great. The surprising fact was observed that at least 90 per cent of the gas was given off within a few seconds on first heating the wire to a temperature exceeding 1500 deg. cent. At a temperature below 1200 deg. however, the gas is given off only very slowly, if at all. The gas consists of about 70 to 80 per cent carbon monoxide, the remainder being mostly hydrogen and carbon dioxide. The total amount of gas evolved from the filament of a 40-watt lamp, if liberated in the lamp after sealing off, would produce a pressure of from 0.006 to 0.02 mm.

3. *Gas from Lead-in Wires and Anchors.* In many of the larger lamps, where the leads or anchors become very hot, there are often clear indications that the gas evolved from this source has a marked effect on the life, particularly on the tendency to arc across during aging. In the experimental lamps made with small sizes of wire, the quantities of gas obtained from this source were found to be too small to measure.

4. *Gas from the Bulb.* On heating bulbs of 40-watt lamps for three hours to a temperature of 200 deg. cent., after having dried out the bulbs at room temperature for 24 hours by exposure in a good vacuum to a tube immersed in liquid air, the following average quantities of gas were given off:

200 cu. mm. water vapor
5 cu. mm. carbon dioxide
2 cu. mm. nitrogen

These are the quantities of gas, liberated by the heating, expressed in cubic millimeters at room temperature and atmospheric pressure.

By raising the temperature of the bulbs from 200 deg. to 350 deg., an additional quantity of water vapor was obtained, so that the total now became

300 cu. mm. water vapor
20 cu. mm. carbon dioxide
4 cu. mm. nitrogen

A subsequent heating of the bulbs to 500 deg. cent caused the total amount of gas evolved to increase up to

450 cu. mm. water vapor
30 cu. mm. carbon dioxide
5 cu. mm. nitrogen

At each temperature the gas stopped coming off the glass after a half hour of heating, only to begin again whenever the temperature was raised to a higher value than that to which the bulb had been previously heated.

It therefore seems that even by heating the bulb to 500 deg., not all of the water vapor can be removed, but it does seem probable that after this treatment the amount of water vapor that can come off a bulb at ordinary temperatures must be extremely small.

This study of the origin of the gases within a lamp thus led to the following important conclusion:

The amounts of residual gas, together with all the gas that is given off by the filament and its supports, are quite insignificant as compared with the gas on the inner surface of the bulb. Furthermore, the great difficulty of completely removing the gases from the glass makes this source particularly troublesome in incandescent lamps. We see that the gases likely to be present or given off in an exhausted lamp are, in the probable order of their importance: water vapor, carbon dioxide, hydrocarbon vapors, hydrogen, carbon monoxide, nitrogen and, when phosphorus is used, various phosphorus compounds.

Effects Produced in Lamps by Various Gases

Small quantities (up to 0.1 mm. pressure) of various gases were let into lamps sealed to the special exhausting system and their behavior during the operation of the lamps was noted. The phenomena observed were extremely varied in character, each gas producing very specific effects. In all cases (except argon) a marked clean-up of gas occurred under proper conditions. These effects have been studied in great detail and are forming the basis for a series of publications from this laboratory on chemical reactions at very low pressures. In the present paper only a very brief outline of the results will be given.

*Hydrogen.** This gas cleans up (disappears) in a lamp bulb in four distinct ways. Relatively large quantities (20 to 50 cubic mm.) of hydrogen are driven on to the bulb when the fila-

*See Langmuir, *Jour. Amer. Chem. Soc.* 34, 1310, 1912.

ment is at relatively low temperature (1500 deg. or more). This hydrogen is particularly active chemically (atomic hydrogen) and will react even at room temperature with many reducible substances. Moderate heating of the bulb will cause a large part of it to escape from the glass again. Since water vapor in the bulb is decomposed by the filament to form hydrogen and an oxide of tungsten, there is nearly always a considerable amount of active hydrogen stored up on the bulb after the lamp has been running some time.

The amount of heat carried away from a filament by hydrogen at low pressures, say 0.001 mm., although many times greater than with any other gas, was found to be entirely negligible compared with the heat radiated from the filament. The cooling effect of such pressures of gas, therefore, has no appreciable effect on the life of lamps, even though, as is usually the case, the lamps are set up at a given efficiency.

Dry hydrogen in lamps was never found to have the slightest tendency to produce blackening of the bulbs. That is, the bulbs never blackened more rapidly than if the filament were run at the same temperature in a vacuum. Subsequent experiments have proved that this is true from low pressures up to atmospheric pressure.

*Oxygen.** At all temperature above 1000 deg. this gas reacts with tungsten to form the yellow oxide WO_3, no matter how low the pressure of the oxygen may be. The oxide distills off the filament and deposits on the bulb, but owing to its light color the deposit is invisible when the amount of oxygen is less than 100 to 200 cu. mm. Oxygen therefore never produces blackening of the bulb.

Nitrogen.† There are three ways in which this gas cleans up in a lamp, each being an exceptionally interesting phenomenon in itself. With voltages above 40 volts and pressures above 0.001 mm. the nitrogen cleans up provided the filament temperature exceeds 2000 deg. and causes an attack of the negative end of the filament, producing a brown deposit of tungsten nitride, WN_2 on the bulb. Except where the amount of nitrogen that cleans up is much larger than could possibly be present in an ordinary lamp this gas never causes any discoloration of the bulb.

Carbon Monoxide. This gas behaves almost exactly like nitrogen. At low pressures it never produces perceptible black-

*Langmuir, *Jour. Amer. Chem. Soc.* 35, 105 (1913)

†Langmuir, *Jour. Amer. Chem. Soc.*, 35, 931, (1913).

ening of the bulb, although at higher pressures it may slowly give a slight deposit of carbon under certain conditions. The results, however, clearly indicated that traces of carbon monoxide such as might exist in lamps, could not be responsible for the blackening.

Carbon Dioxide. This gas attacks the filament and produces carbon monoxide and an oxide of tungsten, without producing any perceptible blackening.

Water Vapor. Even very low pressures of water vapor react with the tungsten filament in a lamp to produce hydrogen, and cause rapid blackening of the bulb. Thus a lamp made up with a side tube containing a little water which is kept cooled by a freezing mixture of solid carbon dioxide and acetone (−78 deg. cent.) will blacken very rapidly when running at normal efficiency, although the vapor pressure of water at this temperature is only about 0.0004 mm.

The fact that lamps exhausted at low temperature (say 100 to 200 deg.) blacken so rapidly during life, together with the fact that water vapor is the principal gas removed from the bulb by heating, indicate that the water vapor is responsible for the short life under these conditions.

It is rather surprising that water vapor should have such a marked effect when either of its constituents, hydrogen or oxygen, acting alone, produces no blackening.

The explanation of the behavior of the water vapor seems to be as follows:

The water vapor coming into contact with the filament is decomposed, the oxygen combining with the tungsten and the hydrogen being evolved. The oxide distills to the bulb, where it is subsequently reduced to metallic tungsten by atomic hydrogen given off by the filament, water vapor being simultaneously produced. The action can thus repeat itself indefinitely with a limited quantity of water vapor.

Several experiments indicated that the amount of tungsten that was carried from the filament to the bulb was often many times greater than the chemical equivalent of the hydrogen produced, so the deposit on the bulb could not well be formed by the simple attack of the filament by water vapor.

Another experiment demonstrated that even the yellow oxide, WO_3, could be reduced at room temperature by atomic hydrogen. A filament was heated in a well exhausted bulb containing a low pressure of oxygen; this gave an invisible deposit of the yellow

oxide on the bulb. The remaining oxygen was pumped out and dry hydrogen was admitted. The filament was now lighted to a temperature (2000 deg. K) so low that it could not possibly produce blackening under ordinary conditions. In a short time the bulb became distinctly dark, thus indicating a reduction of the oxide by the active hydrogen. Further treatment in hydrogen failed to produce any further darkening, showing that the oxide could only be reduced superficially.

Methane. This gas was decomposed, producing hydrogen, while the carbon was taken up by the filament, as was indicated by the resulting change in the electrical resistance. At very high temperatures the carbon distilled out of the filament again. No visible blackening of the bulb occurred in the experiments with methane.

Argon. The behavior of argon was very interesting. Except with high voltages on the filament and very low pressures of argon, no clean-up of this gas could be observed, even on heating the filament up to its melting-point. The slight clean-up which was observed at high voltages was limited in amount. All of the gas which did disappear could be recovered by heating the bulb.

The presence of argon at pressures above 0.005 mm. causes a very large Edison effect and a very rapid blackening of the bulb and attack of the negative end of the filament. The deposit occurs mostly behind the anode, showing that the tungsten atoms in this case are negatively charged.

Although undoubtedly larger pressures of argon may cause serious blackening of bulbs, yet the experiments indicated that this is not ordinarily the cause of blackening in well exhausted lamps. The amount of blackening seemed to depend primarily on the Edison effect caused by the argon, rather than the presence of the gas itself. As the pressure was decreased, the Edison effect decreased even more rapidly, and apparently disappeared entirely long before a degree of vacuum was reached which could readily be obtained with the pump. It seems extremely improbable that the amounts of argon which might exist in an ordinary lamp could perceptibly affect the Edison current or the rate of blackening.

Effects of Other Gases. Many other gases and vapors, such as chlorine, bromine, iodine, sulfur, phosphorus, phosphine, hydrochloric acid, etc., were tried, but in no case did these gases produce blackening of the bulbs. If great care is not taken in these experiments to have the gases extremely dry, very marked blackening will result.

Contrary to earlier experiments, it was found that mercury vapor in a lamp did not cause blackening if the voltage was low enough so that no serious Edison effect occurred.

Attempts to Eliminate Water Vapor

This study of the effects produced by various gases led to the conclusion that if the blackening of bulbs of ordinary lamps was caused by imperfect vacuum, then it must be due to water vapor and the further removal of water vapor would markedly increase the life of the lamps. The problem of improving the efficiency of lamps thus assumed more definite form.

Experiments were next undertaken to detect the presence of water vapor in lamps after they had been exhausted at high temperature. It was found on lighting the filaments of lamps which had been exhausted at 200 deg. and then cooled to room temperature, that there was a steady but slow *apparent* evolution of hydrogen from the filament. However, in some lamps exhausted at 350 deg., there was barely a trace of gas evolved under similar conditions. This evolution of gas served as a measure of the rate at which water vapor diffused off the surface of the glass. It proved unreliable as an accurate measure of the water vapor, because of the clean-up of the resulting hydrogen.

Lamps were next exhausted in the special vacuum oven, so that the temperature of the bulb could be raised during exhaust to a temperature about 100 deg. higher than that otherwise attainable. A good mercury pump was used and care was taken to remove the last traces of mercury vapor, water vapor and carbon dioxide, by placing between the lamp and the pump a trap immersed in liquid air. The lamps were exhausted from one to three hours under these conditions. The filaments were heated to high incandescence to drive off gas. The lamps were sealed off when the pressure by the McLeod gage read about 0.00005 mm. These lamps were put on life test and compared with other lamps made under factory conditions.

The unexpected result of this work was that the life of the lamps exhausted with all these precautions was not materially better than the *best* of the lamps made regularly in the factory. The life of the lamps could certainly not be improved on the average by more than 20 per cent by such methods.

In order to make sure that traces of water vapor were not evolved from the bulb, under the influence of perhaps radiation

from the filament, or some other such cause, some lamps exhausted like those described above were run at an efficiency of about 0.7 watt per candle, with the bulbs completely immersed in liquid air during their entire life. Some similar lamps, exhausted in the same way, were run for comparison with their bulbs at room temperature. A third set was run with the bulbs heated continuously in an oven to about 150 deg. cent. The life of all three sets of lamps was practically identical. Previous tests had shown that lamps exhausted in the ordinary way, when kept at 150 deg. during life, gave a very much shorter life than lamps run at the ordinary temperature. These special methods of exhaust therefore did not improve the life of the lamp above that of an ordinary lamp run under normal conditions, but they did make it possible for a lamp to run with the bulb at a high temperature without serious impairment of its life. This seemed to demonstrate that even the complete removal of water vapor from the lamp bulb would not lead to a very radical improvement in the life of the lamp, although the presence of minute traces of water vapor certainly did cause a marked decrease in the life.

The conclusion to be drawn from all of the foregoing work is that the blackening of the bulbs of ordinary well made and well exhausted lamps is *not* caused by imperfect vacuum.

Among all the causes of the blackening that have been suggested, the only one that remains is evaporation of the filament.

Evaporation of Tungsten

To test out whether or not this was the correct explanation, many experiments were undertaken to determine the rate of loss of weight of tungsten filaments when run at various temperatures in lamps. It was found that in lamps with filaments run at the same temperature the loss in weight was proportional to the surface of the filament and independent of the size of the bulb. The temperature coefficient of the rate of loss of weight was extremely high, as would be expected if it were proportional to the vapor pressure of the metal.

Furthermore, the actual measurements at various temperatures agreed remarkably well with the rational formula for vapor pressure

$$\log P = A - \frac{B}{T} - C \log T$$

From some simple considerations of the kinetic theory of gases, it has been possible to calculate from these data the actual vapor pressure of tungsten at various temperatures. These results will soon be published in the *Physical Review*. It is of interest to give here simply the results at a few temperatures:

Efficiency watts per candle	Temperature (absolute)	Vapor Pressure mm.
1.0	2400 deg. K..	0.000,000,05
0.4	2800	0.000,03
0.2 (melting-point)	3540	0.080
(boiling-point)	5200	760.

Experiments with lamps exhausted at a low temperature have shown that the temperature coefficient of the rate of blackening is much lower than in well exhausted lamps. Thus, lamps exhausted at 100 deg. and run at say 5 watts per candle, often blacken nearly as quickly as similar lamps run at 2 watts per candle, although the rate of evaporation in a good vacuum would be very different. This serves to show clearly the radical difference between the two kinds of blackening.

METHODS OF PREVENTING THE BLACKENING OF BULBS

Having now shown that the blackening of ordinary tungsten lamps is caused by evaporation of the filament, the problem of increasing the efficiency of the lamps becomes a very definite one.

Introduction of Gases at High Pressure. Although in the past it has usually been found that the presence of a high pressure of gas causes an increase in the rate of disintegration of a heated metal,* yet if we know, as we now do in the case of tungsten, that the phenomenon is simply one of evaporation, then we have every reason to believe that the presence of a chemically inert gas will reduce this evaporation. We have seen that low pressures of gases (except water vapor and argon) do not produce any perceptible blackening of the bulb, and therefore produce no

*For example, see a recent paper by J. H. T. Roberts, on "The Disintegration of Metals at High Temperatures," *Phil. Mag.* (6), 25, pp. 260 (1913). He gives evidence that the disintegration of platinum and iridium is due to the formation of a volatile endothermic oxide and not to evaporation. In a future paper the present writer will show that at least in the case of very highly heated platinum in oxygen at pressures as low as 0.1 mm., the rate of loss of weight is due entirely to evaporation and is independent of the pressure of oxygen, although all of the platinum which evaporates from the wire combines with the oxygen to form the oxide PtO_2.

disintegration in the ordinary sense. Most gases react chemically with tungsten at high temperature, but hydrogen, nitrogen, argon, and mercury vapor seem to be chemically inert towards it.

In the manufacture of tungsten filaments it was for a long time the practise to sinter the filament thoroughly by heating it to a high temperature in hydrogen or in a mixture of nitrogen and hydrogen. If care were taken to avoid air or moisture in the "forming gas" the filaments would stand heating for a long time in these gases, which indicated that they were at least relatively chemically inert.

Whether the loss in weight at a given temperature was actually greater or less than in vacuum could not be determined from these rough observations. To test this out, a lamp, was made and filled with carefully dried and purified hydrogen at atmospheric pressure. The filament was run at the same temperature as that of lamps running at one watt per candle. The heat lost from the filament by convection was so serious that actually 17 watts per candle were required to maintain the filament at this temperature. This lamp, however, ran for more than 360 hours without showing any blackening of the bulb, or any greater loss of material from the filament than would have been the case in vacuum at the same temperature. This result was very striking, as the bulb was running hot that the life of a filament in vacuum, in a bulb at the same temperature, would have been very short indeed. Subsequent experiments fully confirmed the first one, and showed that even in the presence of hydrogen at atmospheric pressure, the loss of weight of tungsten was much less than in vacuum. The loss of heat, however, was so great that it would be entirely impracticable to make a lamp with the tungsten filament in hydrogen at high pressure.

Subsequent experiments showed, however, that the heat conductivity of hydrogen at very high temperature was abnormally great—much greater than would be expected from the ratio of its heat conductivity to that of other gases at room temperature. This is due to the fact that at high temperatures hydrogen becomes dissociated into atoms.*

Experiments were next tried with tungsten filaments in mercury vapor. It was found here that the heat loss by convection is extremely small—in fact, so small that a filament could be run for a period of a minute or so, at least, at an efficiency of 0.23 watts per candle. Even the first experiments showed that the

*Langmuir, *Journ. Amer. Chem. Soc.*, 34, 860, (1912).

presence of the mercury vapor very greatly decreased the rate of evaporation.

Experiments were then tried in nitrogen at atmospheric pressure. Nitrogen was found to be entirely inert towards the tungsten, and to conduct so little heat that with a fairly large diameter filament the efficiency was as high as 0.24 watts per candle, at a temperature close to the melting point of tungsten. The rate of evaporation was found to be much less than in vacuum.

For tungsten filaments in these three gases, hydrogen, nitrogen and mercury vapor, the " washing " theory certainly did not apply. On the contrary, instead of increasing, they actually very materially reduced the rate of evaporation.

The next point to be determined was whether the decrease in evaporation was sufficient to offset the heat lost by convection. Because of the presence of the gas, the temperature of the filament was run considerably higher than in vacuum, in order to obtain the same efficiency. Whether or not the rate of evaporation in gas at this *higher temperature* would be less than the rate of evaporation in vacuum at the same efficiency, is a point to be determined only by experiment.

A careful study was therefore undertaken of the laws of heat convection from filaments at high temperature in various gases, since the knowledge on this subject was extremely meager. Experiments were made with platinum wires in air, with platinum wires in carbon dioxide and in hydrogen, and with tungsten wires in hydrogen, nitrogen and mercury vapor.

It was shown* that the heat loss varies with the temperature, according to a simple function of the heat conductivity of the gas; and that it varies with the diameter of the wire according to a rather complicated equation, which, however, accurately expresses the relation between diameter and heat loss. This work indicated that the heat lost by convection increases at high temperatures rather slowly with increase in temperature in the case of nitrogen and mercury vapors, but very rapidly in the case of hydrogen. Further, it was shown that the heat loss from very small wires, say 0.001 in. in diameter, is not very greatly different than that from wires several times this diameter. In other words, it was found that it is much more nearly correct to say that the heat loss by convection from small wires is independent of the diameter, than to say that it varies proportionally with the diameter.

*Langmuir, TRANS., A. I. E. E. 31, 1011, (1912)
Langmuir, *Phys. Review*, 34, 401, (1912)

According to the formulas developed in the course of this work, the heat loss from wires of any size in any of the ordinary gases at any temperature could be calculated.* In this way, the following table was prepared, which gives the calculated relation between the watts per candle and the temperature for filaments of various diameters of tungsten in nitrogen, and in mercury vapor.

Efficiency (in Watts per Candle) of Tungsten Filaments in Nitrogen at Atmospheric Pressure, as Compared to that in Vacuum

Absolute temp.	In vacuum	Diameter in inches						
		0.001	0.002	0.005	0.010	0.020	0.050	0.100
2400°	1.00	4.80	3.13	2.02	1.59	1.35	1.18	1.11
2600	0.63	2.53	1.71	1.14	0.93	0.81	0.72	0.69
2800	0.45	1.54	1.07	0.74	0.62	0.53	0.50	0.49
3000	0.33	1.00	0.71	0.50	0.43	0.39	0.36	0.35
3200	0.26	0.70	0.51	0.37	0.33	0.30	0.28	0.27
3400	0.21	0.52	0.39	0.30	0.26	0.24	0.23	0.22
3540	0.20	0.45	0.34	0.27	0.24	0.22	0.21	0.21

Efficiency (in Watts per Candle) of Tungsten Filaments in Mercury Vapor at Atmospheric Pressure Compared to that in Vacuum

Absolute temp.	In vacuum	Diameter in inches						
		0.001	0.002	0.005	0.010	0.020	0.050	0.100
2400	1.00	2.30	1.77	1.38	1.24	1.16	1.10	1.07
2600	0.63	1.30	1.03	0.84	0.78	0.72	0.67	0.67
2800	0.45	0.84	0.68	0.57	0.53	0.50	0.48	0.47
3000	0.33	0.57	0.47	0.40	0.36	0.36	0.35	0.34
3200	0.26	0.41	0.35	0.30	0.28	0.28	0.27	0.21
3400	0.21	0.32	0.28	0.25	0.23	0.23	0.22	0.22
3540	0.20	0.29	0.25	0.23	0.22	0.21	0.21	0.20

It is readily seen from these tables that the loss of efficiency (at constant temperature) due to the introduction of a gas at high pressure is very much greater for filaments of small size, than for the larger ones, so that with wires of the sizes ordinarily used in lamps the temperature would have to be raised excessively in order to obtain an efficiency of even one watt per candle. Thus in nitrogen a filament of 0.001 inch diameter (the size ordinarily used in a 20-watt, 110-volt lamp) would have to run at 3000 deg. to give one watt per candle. At this temperature

*It makes relatively little difference whether the wires are placed vertically or horizontally. The heat lost *by convection* is usually 5 to 10 per cent less when the wire is vertical than when it is horizontal.

of filament, the life of the ordinary lamp would be about 20 minutes, or about one fifteen-hundredth as long as that when running normally at one watt per candle in vacuum.

With filaments of larger diameter (0.005 inch and more), the loss of heat by convection is not nearly so serious, so that, if the rate of evaporation of the metal is very largely reduced by the presence of the gas, it should be possible to raise the efficiency considerably without shortening the life.

The advantages of a large diameter filament can be practically obtained by coiling a smaller wire into a tightly wound helix or otherwise concentrating it into a small space.

The further development of this type of lamp will be described in the second part of this paper.

Prevention of Blackening

Changing location of the deposit. In lamps with a very high vacuum, the atoms of tungsten as they are given off from the filament by evaporation, travel in straight lines until they strike the bulb. As they are electrically uncharged (this has been demonstrated by experiment), the field produced by the filaments has no influence on the location of the deposit. Since the light from the filament also travels in straight lines, according to similar laws, it follows that in a high vacuum the deposit always collects most on those portions of the bulb where the greatest intensity of light passes through the glass.

In an imperfect vacuum, especially in the presence of argon, the tungsten atoms tend to become negatively charged and thus often deposit on the bulb very irregularly.

With pressures of nitrogen less than 50 mm., the brown deposit of nitride is distributed over the bulb in much the same way as the tungsten deposit in ordinary lamps. At higher pressures than this the effects of convection currents become apparent, and an increasingly large part of the evaporated material being carried to the upper part of the bulb. At atmospheric pressure this effect is very striking, the bulb on a level with the filament usually remaining perfectly clear, while a dark deposit gradually forms on the portion of the bulb (or supports) directly above the filament.

This fact is of great importance in connection with lamps containing high pressures of gas. Not only does the gas decrease the rate of evaporation, but it may be made, by proper design, to entirely prevent the blackening of those parts of the bulb that transmit the light.

SUMMARY

1. The efficiency at which tungsten lamps may be profitably run, is limited principally by the blackening of .the bulb.

2. It has usually been considered, especially among those most experienced in lamp manufacture, that the blackening of ordinary lamps was due very largely, if not entirely, to the presence of residual gases. The evidence which has led to this belief is discussed.

3. The sources of gases with the lamp are studied, and the principal gases are found to be water vapor, carbon dioxide, carbon monoxide, hydrogen, nitrogen, and vapors of hydrocarbons.

4. The specific effects produced by these and other gases are determined. It is found that water vapor is the only one that produces perceptible blackening of the bulbs.

5. The blackening by water vapor is due to a cyclic process in which the water oxidizes the tungsten and is itself reduced to *atomic* hydrogen. The tungsten oxide volatilizes and deposits on the bulb, where it is reduced by the atomic hydrogen to metallic tungsten and water vapor is again formed.

6. Attempts to materially improve the life of lamps by the more complete removal of water vapor result in failure. It is therefore concluded that, although water vapor is usually the cause of the short life of poorly exhausted lamps, yet it is not the cause of blackening in well exhausted lamps.

7. The real cause of blackening in well made lamps is proved to be evaporation of the filament, due to its temperature alone.

8. It therefore follows that to improve the efficiency of tungsten lamps, either the rate of evaporation of the filament must be reduced or the evaporated tungsten must be prevented from blackening the bulb.

9. The following methods of improving the tungsten lamp and thus increasing its efficiency, are then discussed in detail:

Introduction of gases, such as nitrogen and mercury vapor, into the bulb at atmospheric pressure.

Changing the location of the deposit by means of convection currents in gases, so that the bulb opposite the filament does not darken.

10. These methods have met with marked success. The second part of this paper will deal with a particular type of lamp; *i.e.*, a tungsten lamp containing nitrogen at about atmospheric pressure.

A paper to be presented at the 286th Meeting of the American Institute of Electrical Engineers, New York, October 10, 1913.

TUNGSTEN LAMPS OF HIGH EFFICIENCY—II.

NITROGEN-FILLED LAMPS

BY IRVING LANGMUIR AND J. A. ORANGE

The first part of this paper outlined principles upon which radical improvements in the efficiency of tungsten lamps may be based.

It was shown that the desired improvement can be obtained by preventing evaporation of the filament or by preventing blackening of the bulb. By the introduction of considerable pressures of such gases as nitrogen or mercury vapor into the lamp the blackening can be practically avoided and the evaporation of the filament reduced very considerably.

By making use of these principles we have been able to construct practical tungsten lamps which, starting at an efficiency of about 0.40 watt per candle, have run over two thousand hours, the average efficiency during life being better than 0.5 watt per candle. It should be pointed out at the outset, however, that such a degree of improvement as this has been reached only in lamps taking large currents.

In this second part of the paper we will describe the methods by which these results have been attained.

The early experiments with lamps containing nitrogen at atmospheric pressure were made with ordinary single loop filaments of 0.005 and 0.010 inch diameter placed in long heater lamp bulbs. These lamps were set up on life test at such a voltage that the temperature of the filament was 2850 deg. K.

In order to compare these with ordinary lamps, similar lamps with evacuated bulbs were set up on life test with the filaments at the same temperature.

The nitrogen-filled lamps with the filaments 0.005 inch dia-

meter gave an efficiency of 0.65 watts per candle and had a life of about 90 hours, whereas those with the larger filaments (0.010 inch diameter) gave an efficiency of 0.56 watts per candle and a life of about 300 hours. The bulbs opposite the filaments remained clear, although a slight brown deposit of tungsten nitride collected in the upper part of the bulbs. The candle power of these lamps remained above 80 per cent during their entire life, failure being due in every case to breakage of the filament after this had decreased considerably in diameter.

The vacuum lamps, on the other hand, gave an efficiency oi 0.41 watt per candle, but the bulbs blackened rapidly, the candle power falling to 80 per cent in about 40 minutes. Since the filaments of the vacuum lamps burnt out after 2 to 5 hours whereas those of the nitrogen lamps lasted 50 to 100 times as long, it is evident that the rate of evaporation of the tungsten is materially reduced by the presence of the nitrogen.

These results indicated clearly the desirability of using a filament of large diameter. The larger filaments gave not only a better efficiency at any definite temperature, but also a much longer life. Thus doubling the diameter increased the efficiency from 0.65 to 0.56 and increased the life from 90 to 300 hours. The improvement in the efficiency, as was pointed out in the first part of this paper, is due to the relatively greater heat loss by convection from small wires. The life of the filament is determined largely by the loss of tungsten from the filament by evaporation and has been found to be dependent on the *relative* decrease in diameter caused by this evaporation. If the rate of evaporation per unit area from large and small wires were the same, the lives of various filaments run at a given temperature would be roughly proportional to their diameters. However, as the evaporation of tungsten in nitrogen is largely a diffusion process, it probably obeys laws similar to those of conduction or convection of heat from a wire; that is, for wires of small diameter, the actual amount of tungsten evaporated would be nearly independent of the size of the wire. The rate of evaporation *per unit area* would thus be approximately inversely proportional to the diameter. The relative lives of very small wires in nitrogen are therefore nearly proportional to the squares of their diameters.

Design of Filament

These results were decidedly encouraging, for both the efficiency and the life of the lamps can be improved by increasing the diameter of the filament.

It is, however, not desirable to use filaments of very large diameter if similar results can be obtained with smaller ones. The current taken by a filament increases approximately with the three-halves power of the diameter. Thus, for wires of the sizes used in the preceding experiments, the currents needed to maintain a temperature of 2850 deg. were approximately:

Diameter		Current
inches	mm.	amps.
0.005	0.127	3.0
0.010	0.254	8.5
0.020	0.508	24.0

Unless very low voltages are used, the power consumed with the larger wires is so great that only very high candle power lamps can be made.

Therefore it was of vital importance to increase the effective diameter of the filament without decreasing its resistance, and various methods of doing this were tried.

This result may, for example, be obtained by using a tubular filament. The method which has thus far proved most satisfactory, however, is to wind the filament into the form of a tightly coiled helix.

The use of a helically wound filament presents several very interesting features. The life of ordinary single loop filaments is limited by the irregularities in diameter which develop after a considerable amount of tungsten has evaporated. These irregularities, after they first appear, tend to magnify themselves very rapidly, on account of the tendency for the current to overheat any spot which becomes thinner than the rest of the filament. The overheating increases the rate of evaporation and rapidly causes failure.

In the gas-filled lamps, however, when helically wound filaments are employed, a new factor is introduced which entirely counteracts this tendency to overheat in spots. In designing the filaments of these lamps, it is evidently desirable to wind the filament on as large a mandrel as possible, in order to obtain the advantage of the large diameter. Since tungsten is a relatively soft material at the operating temperature of these lamps, too large a mandrel should not be used, as otherwise the weight of the filament pulls out the helix very materially in a few

hours, and the heat lost by convection may thus become greater than if a helix of smaller diameter had been used. In actual practise the filament is designed so that the amount of sagging during life will be perceptible, but not enough to cause too great a change in the characteristics of the lamp.

If, during the life of the lamp, any part of the filament should, for any reason, evaporate more rapidly than the rest, so that the filament becomes somewhat thinner, this portion will have less mechanical strength than the rest and will therefore sag more rapidly. The helix will therefore open out wherever the filament becomes thin or becomes overheated. This will cause increased heat loss both by convection and radiation, and thus prevent local overheating or spotting.

The use of helically wound filaments increases the life of the lamp many times beyond the life that would be obtained with a straight filament running at the same efficiency. This is especially true of the smaller sizes of wire.

Besides the helically wound filament, various other forms have been tried, and, for special purposes, many of these have decided advantages.

Design of Bulbs and Location of Filaments

In the ordinary evacuated lamp, the choice of a suitable bulb is a comparatively simple matter. It must be of convenient size and shape, and provide sufficient room for the proper mounting of the filament. Furthermore, it must have as large an inside surface as possible, so that the density of the deposit of evaporated tungsten will be small. It is also desirable to have the bulb at a sufficient distance from the filament and so related to the power input into the lamp that the bulb does not become overheated. This latter is not only desirable from the view point of safety (in case of lamps for domestic service), but because it is difficult to remove water vapor so thoroughly from the bulbs that the life of the lamps will not be greatly shortened by an overheating of the glass.

In the nitrogen-filled lamps, however, several other factors must be considered, especially in the lamps of high candle power.

In ordinary lamps about 20 per cent of the energy radiated from the filament is intercepted by the glass and causes heating of the bulb. In the nitrogen lamp, beside this radiated heat, there is an additional amount of heat carried to the bulb by convection—an amount varying with the type of lamp and

ranging from 6 to 40 per cent of the total input. The convection currents carrying this relatively large amount of heat travel vertically upwards from the filament and strike a relatively small area of the bulb, which thus tends to become greatly overheated. Unless special precautions are taken, this overheating will cause the liberation of enough water vapor to cause attack of the filament and consequent blackening of the bulb. It is thus highly desirable, in ordinary cases, if small bulbs are to be used, that the filament should be placed in the lower part of the bulb. This has the further advantage that it allows sufficient surface of glass in the upper part for the deposition of the tungsten nitride.

For a similar reason it is generally desirable, although not necessary, to make the bulbs with their height considerably greater than their horizontal diameter.

By special design of the bulb, satisfactory lamps have been made with bulbs of only one-half to one-third as large a volume as that of evacuated lamps of the same wattage. This means that for bulbs of the same volume the nitrogen lamps give roughly from five to ten times the candle power of evacuated lamps. The bulbs of such lamps naturally run much hotter than those of ordinary lamps. The upper parts of the bulbs are often 100 to 200 deg. cent. or more, while the lower parts are sometimes much cooler than this, although closer to the filament.

Several special varieties of heat-resistant glass have been used for the bulbs, making considerably smaller ones possible, as well as rendering it easier to get rid of water vapor. Transparent quartz bulbs have been tried, but do not seem to have sufficient advantage over some of the special glasses to offset their present high cost.

Lead-in Wires and Supports

For some of the larger size lamps which take heavy currents (20-30 amperes) it has been necessary to devise special types of lead-in wires. Platinum has been discarded entirely, even in the smaller sizes. Several types of heavy current leads have been successfully used. Most depend on the use of special alloys which have the same coefficient of expansion as the glass. Bulbs of special glasses into which tungsten or molybdenum wire can be sealed directly, have also been used.

In many of the larger lamps the lead-in wires pass through the lower end of the lamp. In this case they can be made

short. In others, however, the leads are brought in from the top. This requires more care in the construction of the seal if it is exposed to the heat from the convection currents. Screens are sometimes used to protect the seal or other glass parts from direct contact with the convection currents, and to reduce convection.

Various Types of Nitrogen-Filled Lamps

We have seen that at constant temperature, both the efficiency and the life improve as the diameter of the wire is increased. With very large wires (0.020 to 0.040 inch diameter) which take 20-60 amperes, the efficiency may reach 0.40 watt per candle and probably even better, and yet give a life over a thousand hours. It will probably be worth while, in some cases, to use nitrogen in low-current lamps, even if an efficiency no better than that of vacuum lamps is obtained, in order to gain certain other advantages of the nitrogen-filled lamps, such as better color of the light, higher intrinsic brilliancy, etc.

The principal limitation of the new type is therefore that of current. There is no practical upper limit to the current, provided the voltage is not lowered to keep constant power consumption.* With increasing current, larger and larger filaments are used and the efficiency that may be practically reached, increases towards the limit of 0.20 watt per candle, which is fixed by the melting-point of tungsten. Unless special expedients are employed, the cooling effect of the leads lowers the efficiency of the lamps by an amount that is inversely proportional to the voltage and nearly independent of the size of the wire or the current strength.

With voltages of 20 volts or more, this effect is not serious, but for voltages as low or lower than 10 volts, it may become very important.

For the particular type of nitrogen-filled lamp which has at present been furthest developed, it may be said that a life of over 1500 hours is obtained at efficiencies better than 0.50 watt per candle only in large units taking over ten amperes. Lamps running at 0.6 to 0.7 watt per candle have been made in units taking at least 5 amperes.

No serious difficulty has been met in making high-voltage

*As an example, a lamp taking 60 amperes and giving 6600 candle power at 0.40 watt per candle has been successfully run.

lamps. In nitrogen at atmospheric pressure there is no tendency toward arcing, even at 250 volts. Many lamps taking 6 or 7 amperes at 110 volts have been made up and run at 0.6 to 0.7 watts per candle, with a life of over 1000 hours.

A number of special types of nitrogen-filled lamps have been made and tested. Among these the most interesting, for the present, are perhaps the following:

1. *Large Units of Very High Efficiency* (0.4 *to* 0.5 *watt per candle with a life of* 1500 *hours or more*). These take currents of 20 to 30 amperes and (except in units over 4000 candle power) are therefore best run from a-c. circuits by means of small transformers or auto-transformers giving a voltage depending on the size of unit desired. Thus, with 30 volts and 25 amperes, the power would be 750 watts and this, in a lamp of say 0.45 watt per candle, would give 1670 candle power. Higher or lower candle power may be obtained by using other voltages. Typical lamps of this kind are shown in Figs. 1 and 2.

2. *Small Units of Low Voltage.* These take currents of ten amperes or less and voltages as low as four or five volts. The efficiencies with 1000-hour life range from 0.6 to 1.0, or even 1.25 watt per candle, according to the current used.

These lamps are adapted for series street lighting on 6.6-ampere circuits (at 0.6 to 0.7 watt per candle), for stereopticon lamps, automobile headlights and in general wherever a source of high intrinsic brilliancy, steadiness and white color is needed.

3. *Lamps to Run on Standard Lighting Circuits* (110 *volts*). Large units of this type (several thousand candle power) have efficiencies of 0.5 watt per candle or better. With smaller units the efficiency is ordinarily not so high.

A lamp of this type is illustrated in Fig. 3. The leads may be brought in from the top, in which case they are preferably made longer so that the filament remains in the lower part of the bulb.

Special Advantages of the Nitrogen-Filled Lamps

Besides its high efficiency, the features of the new lamps which may, at least for certain purposes, prove of advantage, are:

1. *Color of the Light.* The temperature of the filament being 400 to 600 deg. higher than that of ordinary lamps, causes the light to be of a very much whiter color, so that it comes closer to daylight than any other form of artificial illuminant except the d-c. arc and the special Moore tube containing carbon dioxide.

The color is almost exactly like that which can be had for a few minutes by running an ordinary tungsten lamp at double its rated voltage.

Work is at present under way to develop special color screens

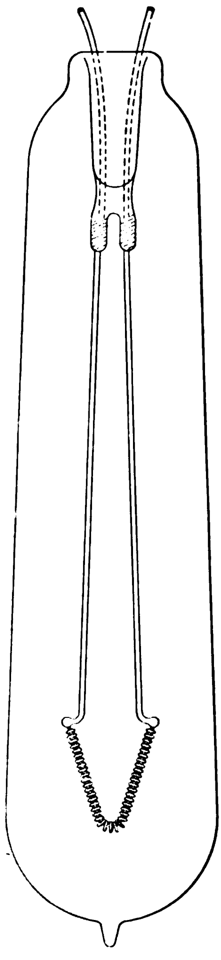

FIG. 1—HIGH EFFICIENCY NITROGEN-FILLED LAMP FOR LOW-VOLTAGE CIRCUIT

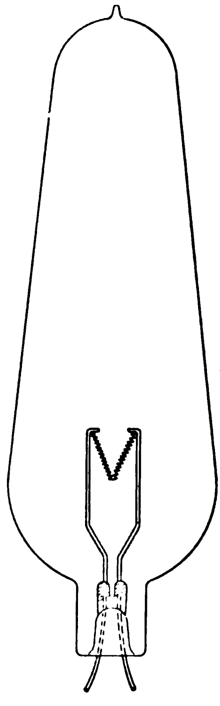

FIG. 2—HIGH EFFICIENCY NITROGEN-FILLED LAMP FOR LOW-VOLTAGE CIRCUIT

which, when used with this light, will give a true daylight color (corresponding to the radiation from a black body at 5000 deg. cent.). From measurements with the spectrophotometer, it can be calculated that the screens which will accomplish this

purpose will absorb from 65 to 75 per cent of the light, so that the net efficiency will be about 2.0 watts per candle for a pure daylight color. At present, to accomplish this purpose with ordinary tungsten lamps, screens must be used which absorb so much light that the net efficiency is between 10 and 12 watts per candle.

2. *High Intrinsic Brilliancy of the Filament.* At the operating temperature of the nitrogen-filled lamps the intrinsic brilliancy

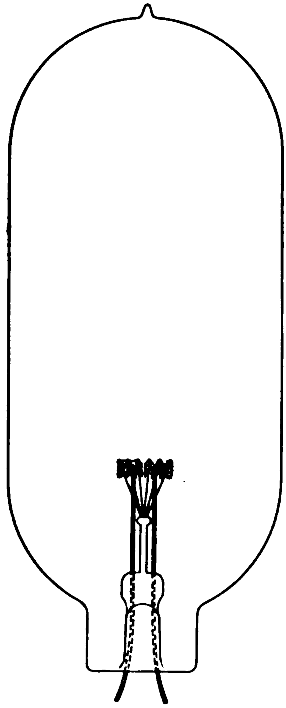

FIG. 3—NITROGEN-FILLED LAMP FOR 110-VOLT CIRCUIT

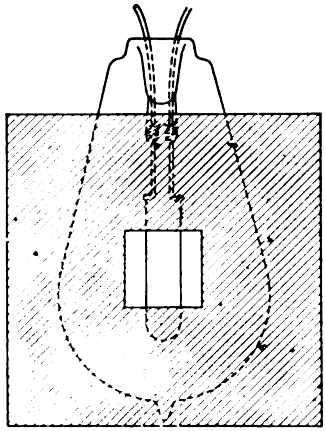

FIG. 4—LAMP AND SCREEN USED FOR CALIBRATION OF BLUE GLASS

of the filament is about 1200 candle power per sq. cm. In ordinary tungsten lamps, on the other hand, running at about 1.25 watts per candle, the filaments have a brilliancy of only about 150 candle power per sq. cm. The brilliancy of the filament of the nitrogen lamp is thus about eight times that of the ordinary lamp.

This feature, combined with the high degree of concentration preferably used, renders these lamps particularly useful for

projection work, such as for headlights or for stereopticons.

3. *Constancy of Characteristics During Life.* It is often possible to so design these lamps that their ampere-,volt-, candle power characteristics remain practically fixed during the greater part of their life. In any case, however, since there is no deposit on the bulb to cut off the light, the candle power practically never falls below 75 per cent (this decrease sometimes being due to sagging). The lamp usually fails by the breakage of the filament with the candle power well above 80 per cent of its original value.

APPENDIX I

Light Distribution of Nitrogen-Filled Lamps. In the preceding paper, wherever efficiencies of lamps have been given, they are expressed in watts per horizontal (international) candles measured in the direction perpendicular to the plane of the filament if this is in the form of a single loop.

Careful measurements have shown that with helically wound filaments the distribution of light in a horizontal plane is almost perfectly uniform, therefore the efficiencies that have been given may be considered to represent also watts per mean horizontal candle.

The spherical candle power of many of the lamps has been measured. The ratio of mean spherical to maximum horizontal (practically mean horizontal also) candle power has been found to average about 84 per cent for the lamps made with single loops of helically wound wire.

It is possible to design the filaments of nitrogen-filled lamps so as to give a maximum of candle power in a given direction. This is being done in stereopticon lamps.

APPENDIX II

Method of Photometry for Nitrogen-Filled Lamps. The usual practise in dealing with incandescent lamps is to determine volts, amperes and candle power either at a predetermined value of one of these quantities or else at a predetermined efficiency by the "cut and try" method. In the case of a lamp which presents so many variables as does the nitrogen-filled lamp, however, it is more systematic to regard temperature as the fundamental variable.

The method that has been adopted for these lamps is not essentially novel, although it does not appear to be as well known as it deserves to be.

First: The temperature has been defined by the equation

$$T = \frac{11230}{7.029 - \log H}$$

where T is the absolute temperature and H is the intrinsic brilliancy of the filament in international candle power per sq. cm. (projected area).*

Second: A most useful criterion in practise for equality of temperature of tungsten filament is that of color-match.

A little practise with the Lummer-Brodhun photometer enables one to judge equality within about 5 deg. if the illumination is good. The most convenient way of setting up temperature standards is to select a number of well-seasoned lamps of high-voltage type in which the anchors are tightly pinched onto the filaments so as to prevent variable cooling effects at the contact. It is best to standardize these, not on a basis of candle power and filament dimensions, but by the aid of a special lamp and diaphragm as shown in Fig. 4. This lamp is arranged at one end of the photometer with the diaphragm in front of and at a known short distance from it. The filament is preferably stout (say 10-mil or 0.025-cm.) so as to admit of good micrometer measurements.

The diaphragm enables one to disregard the end portions of the filament and select a known length of the part which is at uniform temperature. Of course a simple geometrical correction based on the position of the screen is necessary.

It is thus possible to set up the special lamp at any temperature desired by getting the appropriate candle power per sq. cm. from the filament. The standard lamps are brought to color-match with this arrangement and in this way a set of lamps with known relation between voltage and effective temperature is obtained. The life of the ordinary standard lamps would be very short indeed if they were run at the same temperature as nitrogen-filled lamps. For this work, therefore, the standards cannot be used directly as color-standards. For this reason a most important accessory is introduced in the form of a set of special blue glasses. It is not easy to get a blue screen which will perfectly facilitate color-match of tungsten filaments at dif-

*(The derivation of this formula together with a description of other methods of obtaining the temperature of filaments will soon be published, probably in the *Physical Review*.)

ferent temperatures, but a special blue glass has finally been obtained which answers exceedingly well.

Four distinct screens of different intensity are used, each carefully finished as a uniform plate, and any or all of these may be combined with a tungsten filament run at any temperature and the result will color-match correctly against another tungsten filament at a higher temperature.

It may be shown theoretically and experiment confirms that the following relation holds:

If T is the temperature of a filament which is viewed through screens A, B, C, etc.,

T_1 is the temperature of a filament which matches the above.

Then $\frac{1}{T} - \frac{1}{T_1} = a + b + c$ etc.

where a, b, c etc. are constants for the screens A, B, C, etc. Thus one only needs to maintain one standard temperature by means of standard lamps and that temperature can be so low that great permanence is insured.

The constants for the four glasses once determined, there are available a number of standard temperatures ranging from 2250 deg. to 3600 deg. K.

By the use of these screens it is an easy matter to set a lamp up at a voltage such that the filament has a standard temperature, say 2850 deg. To do this it is simply necessary to adjust the voltage so that the color of the light from the lamp is the same as that which comes from the standard lamp when viewed through one of the special blue screens.

Since the efficiency in vacuum is very simply related to the color of the light, this method of photometry gives a very simple and direct way of knowing the exact effect which the nitrogen has on the efficiency of the lamp.

ELECTRIC DRIVE IN MACHINE SHOPS

BY

CHARLES FAIR

1927

ELECTRIC DRIVE IN MACHINE SHOPS

BY CHARLES FAIR

ABSTRACT OF PAPER

To increase production and to decrease cost are two important questions continually before the manufacturer. Since labor is the greatest cost of production, then, where machine tools are a considerable factor in the production, maximum output from the tool is a necessity. Tools that are limited in production because of a lack of power at the tool are a source of expense to the manufacturer. Power cost is low while labor cost is high.

The well designed motor-driven machine of today shows the motor as one of the main elements of the tool, it having short-circuited much of the old mechanical drive, and not as a mere adjunct to the tool. Too little thought is given in many cases to the possibilities of the electric drive for machine tools.

A paper to be presented at the 287th Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 13, 1913.

ELECTRIC DRIVE IN MACHINE SHOPS

BY CHARLES FAIR

The importance of the motor drive for the machine shop is every day becoming more evident. Due to the great improvement in motors, accessories and methods of application and to the large number and variety of motor-driven tools in service today, the relationship of motors and control to machine tools is much better understood by the machine builder and the user than heretofore and, consequently, comparatively little trouble is experienced with either motors or control for the ordinary type of machine tool. Misapplications of both motor and control occur occasionally due largely to insufficient or unreliable information regarding the characteristics of the machine but the number of these misapplications is relatively small. The tendency to both over- and under-motor machines is constantly growing less, owing to the large number of tests made and to accurate information available. There is still, however, a tendency on the part of some machine builders to over-motor their machines either with the mistaken idea of the strength of their machine or with the idea that possibly prospective customers will be impressed with the enormous power that their " heavy type " machines take. Conversely, other manufacturers want to show how little power it takes to operate their " very efficient " machines and consequently get into trouble. These extremes are gradually disappearing and a more normal condition is taking its place. In a comparatively short time the greatly over-motored and under-motored machine will be a thing of the past, at least so far as the general type of machine is concerned. A number of manufacturers have already recognized three ratings of motor drive on certain of their machines; namely,

heavy, medium and light. Much of the existing trouble in motor applications to special machines or to machines rigged for special operations could easily be avoided if only preliminary tests were made with a temporary motor before making the permanent installation. A not uncommon source of trouble, and one that could easily be avoided, is that of attempting to increase considerably the productiveness of a tool by speeding up the machine, increasing the cuts and attaching automatic feeding devices, etc.; all of which increases production but, in doing so, the motor is often overlooked and, if the tool were originally under-motored and the power is not increased, trouble is apt to result. Increased production often calls for an increase in power although there are cases where this is not true.

To increase production and to decrease cost are two important questions continually before the manufacturer today. In the majority of cases labor is the greatest cost of production, thus where machine tools are a considerable factor in the production, the importance of obtaining maximum output from the tool is evident. Although the advantages of the motor drive have been dwelt upon at length numerous times, a brief statement of the advantages derived from electrical installations will perhaps be worth repeating:

Maximum output of tool due to greater power and overload capacity. Too much stress cannot be laid on maximum output of tools.

Closer speed regulation. Allows maximum speed for varying materials and size of work.

Power distribution not only for the tools, stationary or portable, but for cranes, lights, etc. This means that power and light can be had in any part of the building, buildings or yard, permanent or temporary without regard to structural conditions. Numerous belts obstruct light, whether natural or artificial.

Elasticity in the arrangement of tools. Tools can be arranged to the greatest advantage for sequence of operation in routing work and for light as well as for compactness when necessary.

Ease of adding new tools and of moving and rearranging tools. Ease of adding new tools means a great deal in growing plants. Rearranging becomes necessary after reasonable growth or to improvements in methods of manufacture which call for a better routing of work.

Head room for cranes, hoists, etc. For example, note the expensive manner in which work is often handled because of belt or shafting interference with the installation of cranes or hoists.

Facility for running only such tools as are required, for overtime work.

To a large extent the elimination of belts and belt troubles.

Unobstructed light and sanitation.

Under modern structural conditions, avoidance of the well understood difficulties of line shaft installations in concrete buildings.

The general use of high speed steel has made it not only possible, but necessary, for economical production that the cutting speed be increased in order to meet competition. Increasing the cutting speed means more power and while much has been said from time to time regarding the increased production and saving in power due to applying power direct to the tool, yet the writer has very serious doubts if anything like the real importance of this direct application of power is realized in many cases even by those who are advocating it. For instance, the saving of power is looked upon generally as a matter of how much can be saved of the transmission friction load and though this saving may amount to 50 per cent, it is in many cases only a part of the real saving, as proved by numerous tests made by the writer.

The slipping, due to a belt not being able to pull its cut, means waste power and loss of production. If the cut be heavy enough the maximum slip will be reached when the machine is stalled, the power input remaining approximately the same, the loss being entirely one of friction due to slip in the belt. A familiar illustration of the above is that of an operator decreasing the depth of his cut on account of slow down, because the belt will not carry the load. A natural answer to this would be to increase the size of the belts. This will suffice in some cases, but there are numerous instances where either there is not room to increase the width of the belt or if step cones be used the number of steps will have to be decreased and means (such as multiple counters or additional gearing) taken to complete the speed range. Further, it is difficult to shift large belts and this method generally results in much loss of productive time. Tools that are limited in their production because of the lack of power at the tool are a source of great expense to the manufacturer, not only on account of the unproductiveness of the tool, but on account of the excessive labor expense due to the additional time required. The power cost of production is comparatively small, roughly, varying from one to three per cent, while the labor cost is usually a very heavy item of the production cost, say fifty per

cent or upward. If, therefore, by increasing the power on a given tool its output can be increased, the conclusion is obvious.

Up to a few years ago in the majority of shops where motors were used they were usually belted to the lineshaft or countershaft of the tool. Adjustable speed motors were not so commonly used then as now nor were they made in the great variety of sizes and speeds now obtainable. Today, especially in the case of new tools with their requirements of high power and close speed regulation, it becomes not only more convenient, but in many cases almost a necessity to apply the motor directly to the tool.

In driving tools with individual motors it will be noted that the motor not only supplies the power and speeds best adapted to the tool, but that in the case of the variable speed tools the speed range of the adjustable speed motor, alone, will in many cases cover the entire speed range of the tool. The motor and its controlling apparatus should, whenever possible, be connected direct to the tool, thus making a compact unit which has also the additional advantage of allowing the tool to be moved by simply disconnecting the leads and connecting them in the new position. In the case of portable tools this, of course, is an absolute necessity.

Many tests have been and are being made to determine the kind and horse power of motors that should be used for different types and sizes of tools, but up to the present time the motor is generally thought of only as a means of driving the tool and not as to its possibility of becoming one of the main elements of the tool construction. Recent motor improvements will produce many new designs in tools with corresponding higher efficiencies.

While there are numerous motor applications to machine tools which are a decided credit to the machine designers and for which due credit should be given, there are still many motor applications where it is only too plainly seen that the motor is an after-thought and thus much of the advantage of the application is lost. In order to derive the greatest advantages from the motor drive, the motor should as far as possible be direct-connected to the machine. For example, a recent up-to-date motor application to a machine in common use and one that had been motor-driven for several years, abolished belts, three sets of bevel gears, two splined shafts and considerable other gearing; the motor being applied directly to the machine spindle. There are today many cases where motors are driving machines through unnecessary auxiliary apparatus such as belts, gearing, etc. This addi-

tional apparatus not only takes up valuable floor space and wastes power, but fails to give the maximum output available when the motor could be connected directly to better advantage and in some cases at actually less cost. From the foregoing it will be seen that the advantages derived from an up-to-date direct method of applying the motor not only increases the productiveness of the tool, but decreases the actual power required to the extent of the friction load short circuited, and also decreases the first cost of the motor on account of the less capacity required. The writer knows of cases where improved drives have cut the power required to half and even less. A cheap first cost is often an expensive investment.

The advantages of the individual motor drive for large tools and for certain of the smaller tools have been conceded for years, but there are many tools where either the cost of the motor or the cost of applying the motor to the tool on account of the construction of the machine is prohibitive. The motor should be a part of the tool rather than a mere addition to it.

Better drives are possible now than formerly due to the greater motor speed ranges obtainable and to the decrease in dimensions per horse power of the motors, to more perfect balance of the rotating parts and, to a certain degree, to improvements in gears which allow higher speeds without excessive vibration and noise.

The improvements in control appliances have kept pace with the motor development. Much more exacting requirements of both motor and control are now demanded. Motors driving machines reversing ten times per minute, twenty four hours per day are now not uncommon. Duty cycles that were impossible to meet only a short time ago are now not only practicable but common. With the great variety of motors and controllers now on the market and the large quantity sold, sometimes without the manufacturer even knowing for what service they will be used, it would be surprising if trouble did not occasionally occur.

Much of the success of a motor driven machine depends on its control. Magnetic control, which is coming into more general use than formerly, somewhat complicates the control situation. While the possibilities of magnetic control are infinitely greater than the older types of control, likewise the chances for misapplication are greater. However, as the characteristics of the different types of control become better known these complications will disappear.

RELATION OF PLANT SIZE TO POWER COST

BY

P. M. LINCOLN

1935

RELATION OF PLANT SIZE TO POWER COST

BY P. M. LINCOLN

ABSTRACT OF PAPER

The author gives three principal reasons why a central station plant can take care of a given service more economically than a small plant. First, because the first cost per kilowatt of the large units is lower than the corresponding cost of the small units, thereby reducing the first cost and the annual fixed charges. Second, because the operation of a large plant is proportionally less than that of a small plant, and because the large plant can afford to make use of labor saving and other devices which would be out of the question in a small plant. Third, because of the existence of a diversity factor whereby a combined load can be operated with a smaller total capacity than would be required if each part of the combined load were operated separately. The author concludes that the only reasons why central stations should not supply all the electrical service within their territory are that the rates offered may be out of proportion to the cost of the service, or that the customer may have some motive other than the cost of the supply for not using central station service.

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RELATION OF PLANT SIZE TO POWER COST

BY P. M. LINCOLN

That a large plant can supply a given power service as a part of a general power supply business more economically than a plant of only sufficient size for that given service, is so manifest that most engineers are ready to admit it without argument. However, every isolated plant that is installed where central station service is available is, to a certain extent, evidence that there is somebody not yet convinced of this general truth; consequently a discussion showing why this general statement is true may not be out of place.

There are three distinct reasons why a large plant can take care of a given service more economically than a small one. These reasons are:

1. Because the first cost per kilowatt of the large units entering into the construction of a large plant is lower than the small units entering into the construction of a small plant, thereby reducing the first cost of the apparatus necessary for the given service and, therefore, reducing the annual fixed charges thereon.

2. Because a large plant inherently can be operated more economically than a small one, and because, further, the large plant can afford to introduce economies which would be out of the question in a small one.

3. Because of the existence of diversity factor, whereby one kilowatt of capacity in a central station will serve a combined load that would take considerable more than one kilowatt if each part of that combined load were to be served separately.

Further discussions of these three reasons will be taken up in the order named above.

1. Relation of Size and First Cost

A large plant will cost less per kilowatt than a small one. This is simply a specific statement of a general law. The larger the amount involved, the cheaper each unit becomes, no matter what the commodity may be: Kilowatts come cheaper when purchased a thousand in one machine than when bought singly; just as cigars come cheaper by the box, or freight rates are lower by the car load.

Although this law is usually recognized qualitatively, few engineers have an adequate conception of how much it means quantitatively. To give some idea of the extent to which this reduction in cost occurs, a number of curves are given herein showing approximately how much the size affects the cost per kilowatt of some of the types of apparatus that enter into the

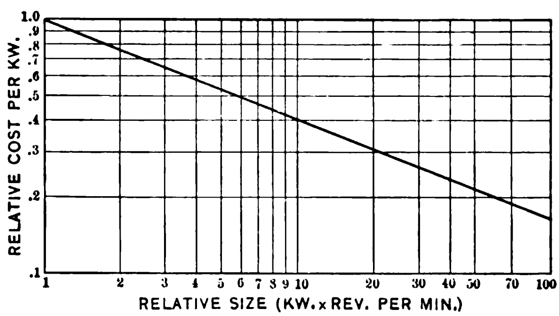

FIG. 1

make-up of a power station. In giving these data, logarithmic cross-section paper is used for two reasons; first, because the range of the data covered in a given curve may be thereby increased, and second, because the law connecting size and cost per kilowatt usually takes an exponential form, thereby enabling us to represent the relation by a straight line on this kind of paper.

Fig. 1 gives data of this nature upon electric generating apparatus. In apparatus of this kind, a variation in size is almost invariably accompanied by a simultaneous variation in speed, and both speed and size have an important influence upon the cost per kilowatt. It is quite possible, however, to take cognizance of the speed variation as well as the output variation and to derive a law that couples the cost per kilowatt with both output and speed. The data given in Fig. 1 are the result of

the inspection of a considerable number of electric generator costs. This curve shows the relative variation of cost per kilowatt as it depends upon size and speed of generator units. An inspection of the curve will show, for instance, that if the speed

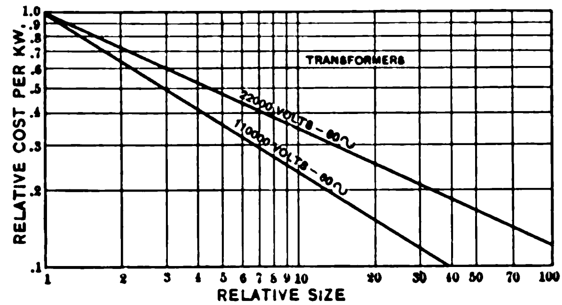

Fig. 2

remains constant the cost per kilowatt will decrease by approximately 65 per cent for an increase of ten fold in the size of the unit.

In Fig. 2 similar data are given for some typical lines of transformers.

In Fig. 3 data are given upon the relative costs of different sizes of boilers.

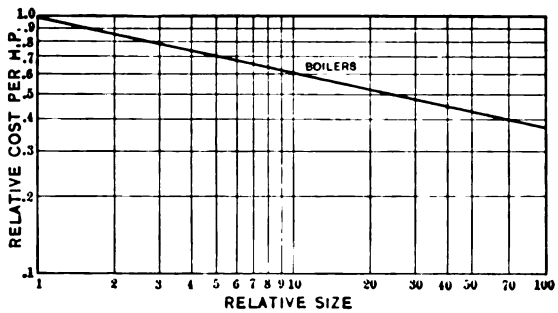

Fig. 3

In using any of these curves it must be borne in mind that a curve is simply a method of stating a general law and that no such general law can take cognizance of an unusual condition. For instance, if we tried to extend the curve for 110,000-volt transformers so as to obtain the cost of a one-kw. transformer, the result would be absurd. When an engineer has designed the

smallest possible transformer suitable for use on 110,000 volts he will necessarily have a transformer of a capacity very much in excess of one kilowatt. In other words, it is impossible to design a transformer of so high a voltage and so low an output. As a consequence, therefore, the use of these curves to obtain relative costs for such conditions would lead to a result which is sadly in error. Common sense must be used in the application of these data.

Comparing a large central station suitable for delivering power for every purpose with the size of a plant that an individual customer of that central station would have to install, if he supplied his own wants, we will find, of course, that the central station plant will be very much larger, anywhere from ten to a thousand fold, possibly even more. However, in comparing complete plants with such a difference in size, we will find that we do not realize the whole of the difference in cost that would be indicated by comparing difference in the cost of the individual parts. The reason for this is that the large plant is inherently more elaborate than the small one. A large plant will naturally be equipped with such items as mechanical stokers, coal and ash handling machinery, coal bunkers and storage yards, superheaters, economizers, condensers with all their auxiliaries, double sets of bus bars, distant control electrically operated switches, heat insulating lagging on all boilers and steam pipes, feed water heaters, water softening plant, etc., some or all of which items may be omitted from the small plant. Although such items cause an increase in the first cost of the large plant, they still do not run its cost up to be as much per kilowatt as the small plant not equipped with these refinements. In the large plant the first cost of these items is more than offset by the operating cost which their use will save and that fact accounts for their use. On the other hand, as the size of the plant is reduced, the point is approached where these cost-saving items may one by one be eliminated, owing to the fact that their presence will lead to a greater resultant cost of power than their absence. It is only where power is produced in relatively large quantities that these various cost-saving devices will pay. This matter will be treated further under the next heading in this paper.

Another saving which would be effected by concentrating power producing apparatus at a single point instead of distributing it throughout the premises of the various customers served is the tremendous aggregate saving in space. As the size of the

units increases, the saving in space occupied becomes marked. For instance, a 10,000-kw. turbo-generator does not take up anything like ten times as much space as a 1000-kw. generator. In fact the space occupied is but little more than for a 1000-kw. unit, and when we compare the space occupied by a 10,000-kw. unit with a 100-kw. unit, the discrepancy is still more marked.

The aggregate saving in space occupied in housing of plant and in the auxiliary equipment will evidently amount to a large item and the comparison of central station power versus individual plants will result in a very material reduction in the first cost of the former compared to the latter.

2. Economies Due to a Large Plant

The reduction in first cost per kilowatt of a large plant over a small one is by no means the only economy from the concentration of a large amount of power generating apparatus at one point. In fact the reduction in first cost is only a small part of the total saving that can be obtained by such a move.

The total cost of power may be divided into two parts; viz. first annual fixed charges (interest, depreciation, taxes and insurance), that depend upon the first cost and second, operating costs (fuel, labor, repairs, supplies, and superintendence) that are almost entirely independent of the first cost. We have just seen that size has a considerable influence on the first of these divisions and now we propose to show this influence is still more marked on the second division. The proportion that fixed charges enter total power costs is usually somewhere between 30 per cent and 60 per cent, being smaller with small plants. The reason that fixed charges increase in proportion as the size of the plant decreases is not on account of the inherent decrease of this item (because, as we have already seen, it really increases) but because operating costs increase with decrease in size much faster than do fixed charges.

A preceding paragraph of this discussion has called attention to the fact that the larger the plant, the greater refinements it can afford to install. The first matter that requires attention as the size increases is usually the matter of fuel saving. In large plants the cost of fuel usually amounts to somewhere between 50 per cent and 75 per cent of the total operating expense. Obviously, therefore, the fuel bill offers by far the best target when one goes hunting for economy. In plants of small output the fuel bill bears a smaller proportion to the total, not

at all because of better economy but because the other expenses, such as labor, superintendence, etc., go down slower than does fuel as the plant size decreases.

The condenser is undoubtedly the most important piece of apparatus so far as fuel economy is concerned. A large plant is almost invariably placed where suitable condensing water can be obtained, whereas a plant for serving the individual customer has to go on that customer's premises and even if the expense of a condenser is warranted, in a great many cases suitable condensing water is not available except at a cost which makes its use prohibitive. The inherent fuel economy of condensing units as compared with non-condensing units is nearly in the ratio of two to one and it can, therefore, be seen at once how large a factor the condenser becomes in the matter of economical operation.

As the plant increases in size we soon come to a point where an investment in superheaters and economizers will begin to pay. The economy effected by these devices in a large plant is of the order of about 10 per cent of the fuel. When our fuel bill is of the order of 50 per cent of the total cost of power, it is evident such a saving will justify a very considerable expenditure. As the plant output grows smaller, however, the fuel bill becomes a constanty decreasing proportion of the total cost and at the same time the relative cost of superheater and economizers increases, so that we soon arrive at a point where their installation will no longer pay. It is only the plant of comparatively large output that can afford to use this economy.

Uniformity in fuel supply is another item which is of very considerable importance, as is realized by those who have been obliged to change the quality of fuel fired from time to time. The grates, draft, combustion chamber, etc. suitable for one kind of fuel may not be at all suitable for another, and the insurance of a uniform fuel supply is not within the power of the user of fuel in comparatively small quantities. It is only large plants which buy fuel at wholesale that can afford to have a guaranteed and uniform supply. The purchase of fuel under specifications is a refinement in fuel practice that has come into very considerable vogue within the past five or ten years. It is only such plants as use fuel in large quantities that can avail themselves of the uniformity of fuel supply which the purchase of fuel under such specifications will insure.

Some of our larger central stations have found that uniformity in the size of the particles of fuel has an important bearing on

the economy with which it can be burned under boilers. In some plants it has been demonstrated that it is economy to screen the fuel so that dust and small particles may be separated from the larger and burned in a separate furnace particularly designed with that end in view. It is evident that only a plant having a comparatively large fuel consumption can afford to enter into such a refinement in the use of its fuel. Here is another economy that is available only in a larger plant.

After fuel, labor is the next largest of the items that go to make up operating cost. In the large plants it is possible to introduce labor saving devices, that would be out of the question in the small plant. Probably one of the greatest labor saving devices in the modern power plant is the mechanical stoker. Not only does the mechanical stoker save labor but it also gives an ability to force boilers to a point not possible with hand firing. Thus an indirect saving comes from the use of mechanical stokers (in reducing boiler equipment necessary during peaks) that is as great, if not greater, than their effect in the direct saving of labor. In the small plants the installation of mechanical stokers is not justified, because, even with hand firing the boiler room force is so small that it could not be further reduced by introducing stokers.

Again when we come to analyze engine room labor, it is evident that a 10,000-kw. turbo-generator does not require much more attention than a 100-kw. unit. Each unit has about the same number of bearings and there is little inherent reason for the large unit requiring much more attention than the small one. When we compare them on a per kilowatt basis, the large unit, of course, has a tremendous advantage in labor cost.

In a small plant we will find that the coal supply is brought in from the coal pile in a wheel-barrow and shovelled into the furnace by hand. In the large plant the incoming coal is dumped by gravity from a hopper car and carried almost automatically by machinery into bins above the furnaces where it is fed by gravity to the grates. The difference in labor is, of course, very marked, but it would be ridiculous for the small plant to attempt to use such coal handling machinery, because the amount of labor which it could save would not begin to pay for the fixed charges on the machinery.

The removal of ashes is another point wherein the large plant has an advantage on account of its size. The small plant must have them raked out by hand, loaded into a wheel-barrow and

hauled away to a pile that is again moved by hand when a sufficient amount has accumulated. The large plant dumps them into a tram-car that takes them directly to a hopper car for disposal at once.

Another item of economy which can be exercised by the large plant, but is prohibited to the small one, is that of adjusting the apparatus to the load to be carried. A large plant usually is equipped with a comparatively large number of units and can operate them so that the units are run near their maximum economy point. On the other hand, a small plant is usually equipped with a relatively small number of units and must often run a unit considerably larger than necessary to take care of the load and consequently operate it at a relatively low point on its economy curve.

And so one may go on indefinitely and enumerate the advantages and economies of the large central station. If the boiler feed water is bad, the large plant can afford to install a water softening plant; the small plant cannot think of such a refinement. The large station can afford to insure itself against a coal miners' strike by installing a coal storage yard, and to insure itself against electrical breakdowns by spare units, spare cables and a double set of buses—refinements that would be entirely out of reach of the individual small plant.

It is evident, therefore, from the foregoing analysis that not only does the central station have an advantage in first cost but that it has a much greater advantage both in operating cost and in the ability to insure continuity of service.

3. Diversity Factor

Now we come to the third advantage of the large central station serving a diversified load. As the name indicates, diversity factor might be defined as the advantage in capacity which is secured by the large plant serving many different kinds of loads over the aggregate capacity of the many plants that would be required to serve each individual part of this load separately. Not only is the large station cheaper per kilowatt than the small one, but also the large plant does not have to have as many kilowatts of capacity installed to take care of a given aggregate load as would individual plants for taking care of the same service.

The diversity of two or more loads may be complete or only partial. Diversity may also occur on account of either yearly

or daily fluctuations in the time that the maximum of a given load occurs. As an example of yearly fluctuations we might cite, as summer loads, ventilating fans, irrigation, pleasure parks and ice making; as winter loads, electric heating (as for street cars and houses) and electric lighting during the early hours of the daily lighting period. As examples of diversity factor due to daily variations we might cite power for the operation of factories during the day and the power required for illuminating the streets at night. These are examples where the diversity is nearly, if not quite complete, as there is no coincidence whatever of the times at which such loads must be carried.

Partial diversity is always secured between two loads unless the loads vary in exactly the same proportion at exactly the same time. Such a coincidence is impossible, and as a consequence any loads will have some diversity in the times at which their maxima will be taken.

One of the best examples of diversity that the writer knows of is the use of one of the United States Government irrigation plants in the west for house heating during the winter months—a use which was called to my attention by Mr. O. H. Ensign, Chief Engineer of the United States Reclammation service. The power plant in this case was installed primarily for the purpose of pumping water for the irrigation of some of the arid lands of Idaho. The irrigation season in Idaho opens in April and closes usually in September, operating for this purpose only during the summer months. During the winter months there is ample water to run the plant and practically the only expense of its operation during the winter is the labor necessary for attendance. It is evident that the machinery will have less depreciation if operated during the winter months than if simply shut down and left uncared for. There is not the same chance for the apparatus to absorb moisture and it will unquestionably be in a better shape for this operation than if not operated during the winter.

In this Idaho irrigation district, advantage is taken of this condition by supplying electric heat to the farmers during the winter months at a price that will simply pay the cost of operation. This policy results in a price of the order of one-tenth cent per kw-hr. With such a price, one dollar will buy 3,420,000 B.t.u. With coal running 10,000 B.t.u. per lb. and selling at $4.00 per ton (which is certainly a favorable statement of the fuel conditions in this district) one dollar will buy 5,000,000 B.t.u. An

efficiency of 50 per cent is certainly all that can be expected in burning fuel for house heating purposes, while with electric heat one cannot avoid an efficiency of 100 per cent. As a consequence, we have the condition where the farmers of Idaho are able to heat their houses by electricity actually cheaper than by coal, to say nothing of the greater convenience and cleanliness of the electric method of heating—and this all comes on account of the existence of diversity factor.

Complete diversity occurs only with certain limited kinds of service; partial diversity occurs on every kind of service. The amount of partial diversity which occurs depends entirely upon the nature of that service. Mr. H. B. Gear, in an interesting paper read before the Chicago Section of this Institute in 1910, gives some valuable data on the question of diversity factor. He found, for instance, that in residence lighting the diversity factor amounted to over six, that is, the sum of the maxima of a considerable number of residences was over six times as great as the maximum required from the generating station to serve all of these residences. For commercial lighting, that is, the lighting of retail stores, etc. he found a diversity of nearly 2½; for small scattered service he found a diversity of practically the same figure and for large users the diversity was still 1.4. Possibly this last figure is the most significant of all. It is the large user who would be tempted to install a plant for his own operation. Residence lighting and small scattered power, etc. use such a small quantity of energy that there is practically no incentive for such users to provide their own power. However, the fact that the large user still has a diversity as high as 1.4 is, of itself, sufficient to enable a large central station to supply power to such users cheaper than they can make it themselves. This one consideration, independent of the others that are discussed in this paper, is sufficient to justify the central power station, because it means the installation of less than three-fourths the amount of apparatus in a central station than it would require in separate individual plants for giving the same service.

Even where various services are of the same kind there is a considerable amount of diversity. Mr. Samuel Insull, in an interesting and instructive paper read before this Institute in April, 1912, has shown this to be true. He finds, for instance, that the diversity for the operation of the various steam railroads centering in New York is of the order of some six or eight per cent. When it is borne in mind that this is the diversity for the same

kinds of service, it is evident that the diversity between different kinds of service will be very much greater. It is important, therefore, that a central station diversifies its service just as far as possible. For instance, a plant whose main business is to supply lighting and general power can take on a railway load more economically than can a plant whose output is already being taken by railroads. On account of the diversity between these different types of load, the addition of a railway load may be assured by a plant already carrying a general power and lighting load with the addition of less apparatus than required by a separate plant to serve the same load. Concentration of power supply makes for economy in every aspect.

There are two arguments that may, with reason, be urged against the central station method of supply. The first is that the central station requires the addition of a transmitting and distributing system before its customers can be supplied and the cost, upkeep and losses in this transmitting and distributing system must be added to the central station to make it comparaable with individual customers' plants. This argument is entirely legitimate, as far as it goes, but it does not go far enough. The cost and losses of the transmitting and distributing system do not amount to enough to begin to offset the advantages on part of the central station that have been detailed in the preceding pages. It is, of course, possible to imagine a condition where the cost and losses of transmission and distribution make the central station supply more expensive than an isolated plant but this means that we have gone beyond the proper radius of that station. The advantages (in the matter of cost) of the central station are so great that the utmost addition, on account of transmission and distribution, and still maintain good regulation, are not sufficient to permit isolated plants to compete.

The second argument in favor of the isolated plant is that during the season that heating is required the steam may be used twice, once for power and the exhaust for heating. This is also a legitimate argument so far as it goes and its complete discussion requires much more space than I have at my disposal here. In general, however, it can be shown that the advantages which accrue to the centralization of a large amount of power at one point will far outweigh the advantage of the isolated plant even when it is coupled with the heating proposition, as it so often is.

When the isolated plant is used for heating, we must bear in

mind that there is a large part of the year, certainly more than one-half of it, when no heating whatever is required and during this period the plant must accept the losses which are inherent with the combination of power generating and steam heating plant using the same steam. Another thing which must not be forgotten is the daily diversity between the heat and power loads in the isolated plant. Take for example, the case of an office building. The building will, of course, cool off to a certain extent during the night and it is required that it be brought to a certain acceptable temperature by the time the office force arrives in the morning. This will require a considerable amount of steam during the early morning hours at which period there is absolutely no use for light in the building and practically none for power. The heavy demand for light and power in this same office building will occur just before the force is getting ready to leave for the night and at this particular period of the day the requirements for heat are at a minimum because the heat inertia of the building is sufficient to keep up the temperature at this time, and it is useless to put in more heat at the time when the force is getting ready to leave. Therefore, while it is perfectly true that the same steam can be used economically for lighting and heating, it is impossible to so arrange a combination plant of this kind that the diversity in time requirements for the different kinds of service make it possible to make complete use of this advantage. This is a case where diversity works against and not for economy.

As a result of the foregoing analysis, the writer is of the opinion that there are only two reasons why central stations should not supply all of the electrical service within legitimate reach of their distributing systems. These are, first because the rate offered by the central station does not bear a suitable relation to the cost of the service to be supplied, and

Second, because the prospective customer has some motive other than the cost of the supply for not taking his service from the central station.

INDUSTRIAL SUBSTATIONS

BY

H. P. LIVERSIDGE

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ABSTRACT OF PAPER

The author traces briefly the engineering development of "industrial substations", by which term he designates installations of electrical plant equipment in consumers' premises, receiving electrical energy from a central station system.

A discussion is entered into of the factors governing the design and installation of this class of substation and four factors are advanced as determining the design: (1) Space economy; (2) Operating requirements; (3) Fire hazard and safety to attendants; and (4) Costs.

Descriptions are given of some twelve industrial substations which are taken as typical installations and which are at present in operation in this country. Numerous diagrams and illustrations are given of the various plants. At the conclusion of the descriptions, detailed discussion is undertaken in a further analysis of the four factors enumerated as they relate to the twelve plants which have been described.

A paper to be presented at the 287th Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 13, 1913.

INDUSTRIAL SUBSTATIONS

BY H. P. LIVERSIDGE

The growth of the demand for electrical energy during the last two decades has been one of the very significant indications of the increasing prosperity of the country at large. Remarkable growth is noted in the demand for electrical energy for all uses, but particularly in the demand for energy for industrial purposes. This latter demand has created certain problems which have necessitated the development of new methods by which energy is delivered to consumers.

It is the purpose of this paper, after tracing very briefly the engineering development of this branch of the central station industry, to give some discussion of the salient features of the design and installation of electrical plant equipment in consumers' premises, which we shall designate as " industrial substations." Certain specific installations will be cited and certain conclusions drawn.

The growth of the supply of electrical energy, by central stations to consumers, for industrial purposes, dates back to the commercial introduction of the electric motor. Starting with the early installations of a few horse power each, the development has been such that at the present time industrial consumers are found with individual installations totalling several thousand kilowatts capacity.

In the early days the industrial consumer was supplied like other consumers, from the regular service mains of the central station. The service was either d-c. or a-c. according to the character of the central station mains. Energy was supplied without the necessity of installing transforming or switching

equipment in the consumer's premises, other than the usual service switches controlling the incoming lines.

It was early seen by operating companies that, due to the increased demand, the method by which energy is brought to the consumer and there distributed would have to undergo marked changes, and that it would be necessary to devise means by which the large blocks of energy demanded could be satisfactorily supplied by the central station. The changes necessary to accomplish these results have affected particularly: (a) the size and location of the transforming apparatus, (b) the character of the equipment required to control these increased capacity installations, and (c) the voltage at which the energy is delivered to the consumer.

Coupled to the greater demand of the industrial consumer supplied from high-voltage alternating-current lines was, oftentimes, the need for direct-current service. This added requirement necessitated the installation of rotating apparatus for transformation from alternating current to direct current, besides the static transformer equipment usually provided.

These larger and more complicated installations practically made necessary the location of the transforming apparatus in the consumer's premises. In addition, many of the larger services made advisable the supply of energy at a higher potential than that of the regular distribution circuits of the central station system, particularly so when the distance of transmission was comparatively long.

The installation of high-voltage services supplying static transformers or rotating transforming apparatus, or both, necessitated an electrical equipment comparable to that installed in central station substations. Moreover, the same care is given to the design and construction. This is clearly evidenced in the industrial substations later cited as examples in this paper.

The present discussion will deal more particularly with large industrial substation installations located in comparatively built-up manufacturing districts, and supplied from high-voltage alternating-current lines. At the outset, consideration must be given to the factors that determine the decision on the part of the operating company whether or not to install a substation in consumers' premises.

In general, when the load does not exceed a few hundred kilowatts and the consumer's demand is for alternating current entirely, it is very usual practise to supply the consumer through

an installation of transformers fed directly from the distribution lines of the operating company. In such cases, no substation is necessary in the consumer's premises.

On the other hand, when the amount of energy demanded requires a heavy capacity transforming equipment, or when the requirements of the consumer are such that a combination service of both direct current and alternating current must be supplied, then it becomes necessary to install protective apparatus and switching equipment of a more elaborate nature than in the former case; and the industrial substation is therefore designed.

The problem of electrical design of industrial substations presents usually no great difficulties. The equipment necessary to meet the requirements of each consumer will be found to have been more or less standardized by the operating company, with such modifications in particular instances as are necessary.

The variations between designs are due in general to differences in the capacities of the installations, the equipment installed, the conditions of service, and the voltages at which the substations are supplied.

The problem of *physical* design very often presents many more difficulties, particularly the disposition of the electrical equipment in the space available. The four factors of: (1) space economy, (2) operating requirements, (3) fire hazard and safety to attendants, and (4) cost, govern in most cases the physical layout.

Not infrequently a decided limitation is imposed on the physical arrangement by the very cramped quarters allotted to the substation equipment by the consumer. On the other hand, the erection of new industrial buildings usually allows space sufficient for proper design of the substation. In the matter of the design of industrial buildings, much room exists at the present time for closer co-operation between the consumer and the central station's engineers, to the consumer's own great advantage.

Contrasts are evidenced both in the electrical and physical designs of industrial substations in different localities in this country, but are no more marked than in the designs of generating stations and substations. It is proposed later herein to cite examples of industrial substations in operation in different parts of the country, and to give descriptions of certain which are taken as typical.

For purposes of further analysis, the electrical design of an industrial substation briefly may be divided into the following components: (a) the incoming feeders; (b) the arrangement of the busbars if any are installed, and the switching equipment; (c) the transforming equipment; and, finally, (d) the distribution system of the consumer. This latter is very often left to the consumer himself, and usually is given little attention by the central station engineers.

Detailed discussion of the various components which make up the electrical equipment of an industrial substation as noted above, need not be taken up at this point, but rather consideration will be given to them as they are instanced in the following examples of typical installations, at present in operation in this country.

Plant No. 1

Silk Manufacturing Plant Supplied by Two Industrial Substations Located on Premises. Static transformer equipment only is installed, totalling 1720 kw. in the two substations. The load is of very constant nature, and the service is twenty-four hours a day, seven days a week throughout the year. No regular attendant is required, but general maintenance is provided by consumer's electricians.

The description will be limited to the more recent one of the two substations, which is a fireproof building, 10 ft. (3.04 m.) wide by 30 ft. (9.14 m.) long by 10 ft. 6 in. (3.19 m.) high at lowest point, of brick with concrete; one side adjoins a factory building. Ample provision is made for lighting and ventilation by window openings (fire-resisting glass) and by natural-draft ventilators in the roof.

The substation is supplied at 2400 volts, two-phase, 60 cycles, by two feeders, both entering the building underground from overhead lines. Lightning arrester protection is provided by electrolytic lightning arresters connected to the overhead lines and located in enclosures at the base of the terminal poles.

The present transformer equipment consists of two banks of oil-insulated self-cooled power transformers of 400 kw. capacity each, and one bank of lighting transformers of 60 kw. capacity; making a total of 860 kw. capacity in this substation.

The high-tension switchboard consists of four panels, controlling two incoming feeders and two transformer banks. Connections are as shown in Fig. 1 under "Transformer House No. 2." Automatic hand-operated oilbreak switches are connected in each 2400-volt circuit as shown in the diagram.

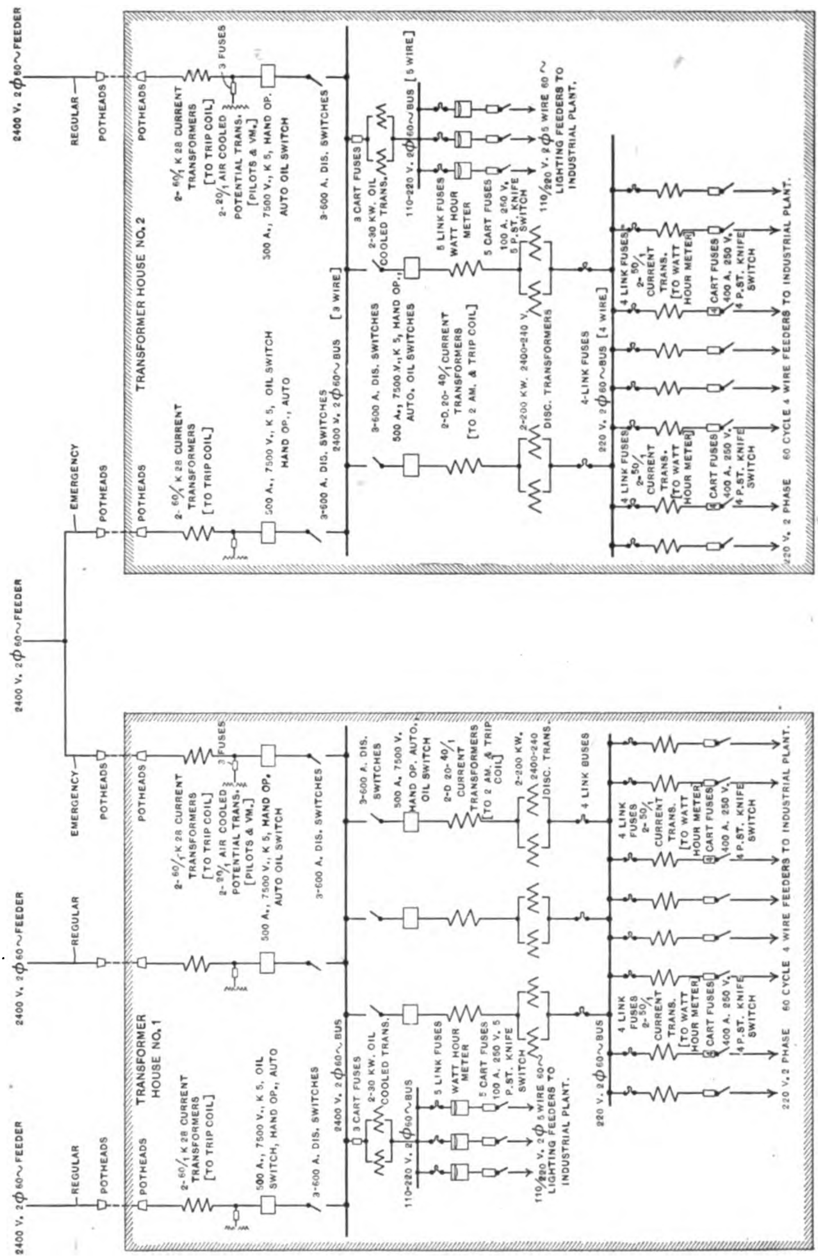

FIG. 1—ELECTRICAL CONNECTIONS OF PLANT NO. 1

All metering is done on the low-tension side of the step-down transformers and the watt-hour meters are connected in the individual industrial feeders. The power feeders are 240-volt, two-phase, four-wire, and the lighting feeders 120/240-volt, two-phase, five-wire. All high-voltage wiring in the plant is placed out of reach of attendants and all high-voltage disconnecting switches, busbars, and instrument transformers are protected by asbestos lumber barriers. All power secondary fuses are protected by asbestos shields, and all lighting secondary fuses are enclosed in iron boxes.

The accompanying illustration (Fig. 2) gives a general view of the electrical equipment.

Plant No. 2

Grain Elevator. Substation Located in Specially Designed Two-floor Brick and Concrete Building. This substation is supplied by 13,200-volt three-phase 60-cycle overhead feeder from substation of central station company.

The present transforming equipment consists of three 200-kw. oil-insulated self-cooled single-phase transformers stepping down to 440 volts three-phase three-wire. The ultimate total transformer capacity is 1200 kw. in two banks. Electrical connections are as shown in Fig. 3.

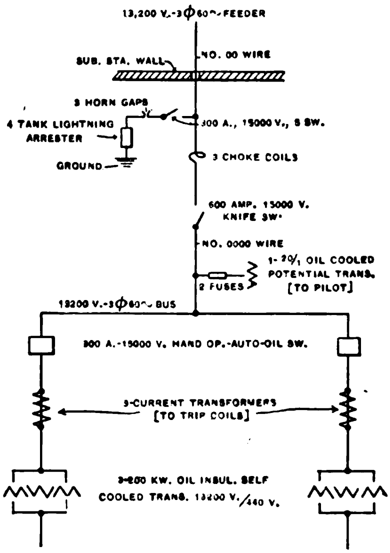

FIG. 3—ELECTRICAL CONNECTIONS OF PLANT NO. 2

Electrolytic lightning arrester equipment with choke coils is installed on incoming feeder at the point of entrance to the substation building. This feeder is taken directly to the two automatic oil switches controlling the two banks of step-down transformers.

All metering is done by watt-hour meters on the low-tension sides of the transformers; the three-wattmeter method of three-phase energy measurement is employed. All oil switches are hand-operated, and the electrical design is essentially one of simplicity.

Provision is made for the safety of the operator by the erection

FIG. 2.—PLANT NO. 1 [LIVERSIDGE]

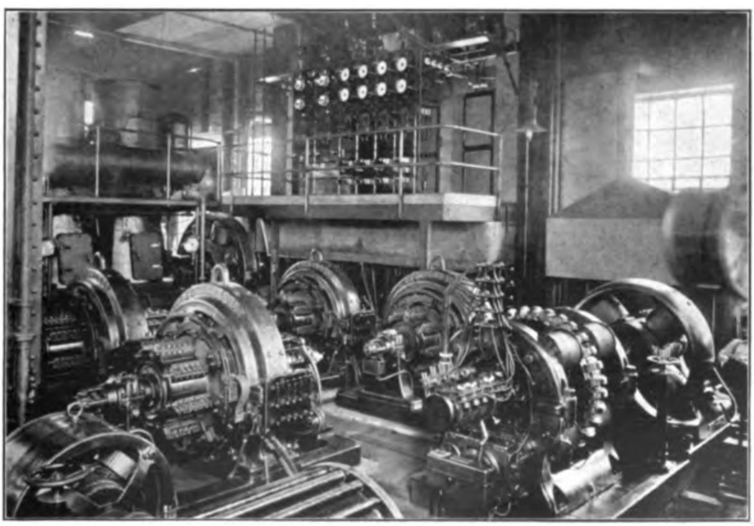

FIG. 4.—PLANT NO. 3 [LIVERSIDGE]

of asbestos lumber barriers, etc., enclosing all accessible high-voltage conductors and parts.

The character of the load is irregular.

Plant No. 3

Ship and Engine Building Plant. Synchronous Converter Substation Located in Consumer's Power House. The substation equipment consists of four 300-kw., 60-cycle synchronous converters, having a total capacity of 1200 kw. and supplying direct-current energy to consumer at 250 volts, two-wire. The substation is arranged for parallel operation, if desired, with two engine-driven direct-current generators of the consumer. The substation is supplied by two 6000-volt, two-phase, 60-cycle

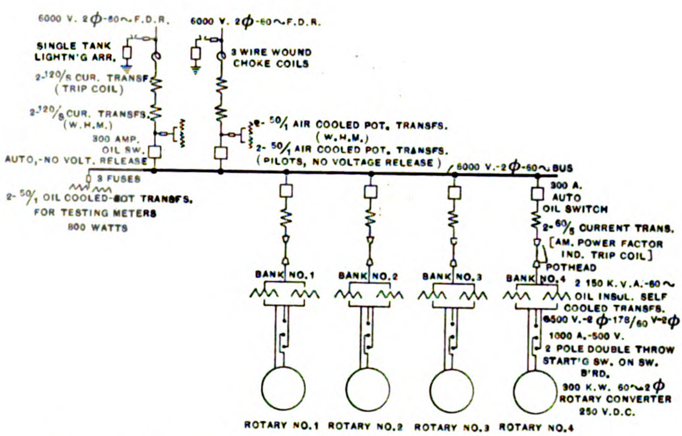

FIG. 5—ELECTRICAL CONNECTIONS OF PLANT NO. 3

feeders brought overhead into the building and connected to a single set of busbars.

Electrolytic lightning arresters and choke coils are installed on each feeder, and automatic oilbreak switches are provided for each feeder and each synchronous converter circuit. The feeder oil switches have a "no-voltage release" feature in addition to the usual overload trip.

All energy is metered by watt-hour meters placed on the two incoming feeders. All high-tension switching equipment and the alternating-current switchboard, busbars and lightning arresters are located on a gallery along one side of the building. The oil-insulated self-cooled transformers for the synchronous converters are located underneath the gallery.

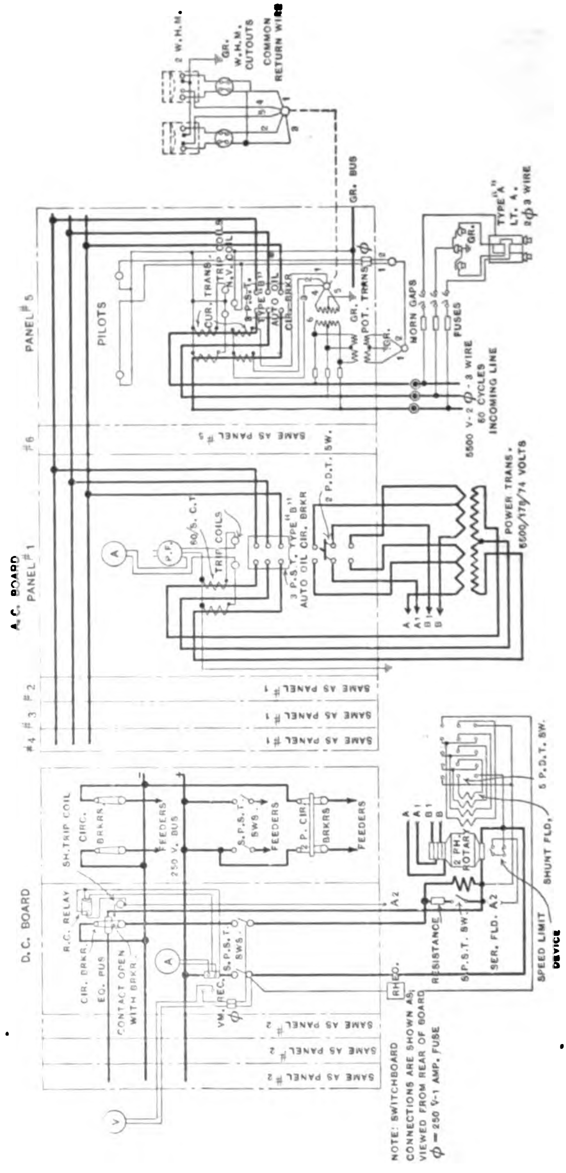

FIG. 6—DETAIL OF ELECTRICAL CONNECTIONS, PLANT NO. 3

A general view of plant is given in Fig. 4 and single-line diagram of connections in Fig. 5. Detail connections for the electrical equipment are shown in Fig. 6. Interest attaches to the sheet metal hoods placed over the transformer banks and used for purposes of fire protection and ventilation.

The conditions of service are twenty-four hours, six days a week. Attendance is by the regular operating force employed by the consumer.

Plant No. 4

Static Transformer Substation (Fig. 7) Supplying Amusement Park on Outskirts of Metropolitan District. The equipment is located in a small brick substation building on the park grounds, and consists of 400 kw. transformer capacity at present time, with provision for doubling this capacity when required. Transformation is from 6000 volts, two-phase, 60-cycles, to 2400 volts, two-phase, 60-cycles. Oil-insulated, self-cooled transformers are used. Energy is metered on the low-tension side of the transformers. All oil switches on the high-tension side are non-automatic, for the reason that there is no regular attendant and further that the feeder which supplies the substation is brought directly from a central station substation where the feeder switches are automatic. Electrolytic lightning arrester equipment is installed at both ends of the feeder.

The character of the load is a summer park load of motors and lighting.

Plant No. 5

Synchronous Converter Substation in Car Manufacturing Plant. This is supplied at 13,200 volts, three-phase, 60-cycles, by two underground feeders from a central station substation.

The initial equipment consists of two 300-kw., six-phase, 250-volt, direct-current compound wound synchronous converters with necessary banks of single-phase oil-insulated self-cooled "step-down" transformers. The ultimate converter capacity is 1600 kw. in four units. A single set of high-tension busbars is provided, and the entire high-tension switching equipment is electrically remote-controlled. Also, a high-voltage service is taken off the busbars to additional transformers for fire pump motor. Watt-hour meters are connected on the 13,200-volt incoming feeders.

A specially designed two-story substation building houses all the apparatus. The building is entirely inside the walls of the

industrial plant, but is separated from it by suitable fire-proof walls. The static transformers and high-voltage equipment are located on the second floor; the synchronous converters, the direct-current switchboard and the remote control board for the high-voltage oil-break switches are placed on the first floor.

The plant operates in parallel with an existing direct-current steam-driven plant.

An interesting point in connection with the consumer's distribution system is the provision for electrical remote control of the 250-volt direct-current supply switches which are located in various parts of the manufacturing plant. These separate services are tapped to heavy capacity feeders, arranged in a ring system, and the service switches are controlled from the industrial substation.

The character of service at this plant is ten hours per day, six days per week, and the attendance is supplied by the consumer.

Fig. 8 shows elevation of the substation and illustrates the general arrangement of the electrical equipment.

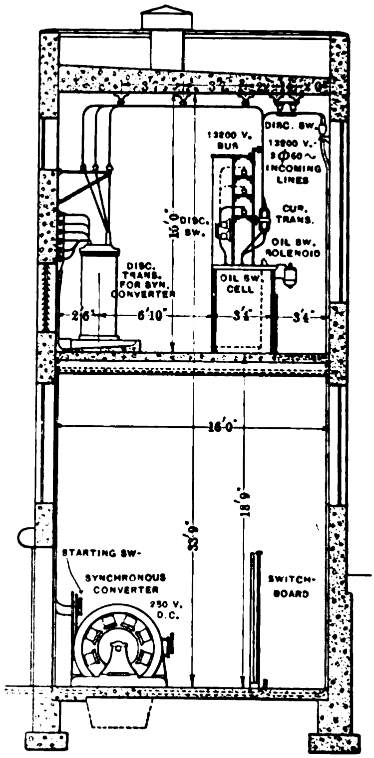

FIG. 8—SECTIONAL VIEW OF PLANT NO. 5

Plant No. 6

Static Transformer Industrial Substation of Paper Manufacturing Plant. Current is supplied at 6600 volts three-phase by two incoming feeders, one of them brought directly from generating station and the other from a substation.

The transforming equipment consists of six 150-kw., 6600/440-volt, single-phase power transformers, arranged in two banks of three transformers each, giving a total connected capacity of 900 kw.

The feeders are taken through automatic oil-break switches to a single set of busbars connected to a line containing current

transformers used in connection with totalizing instruments and meters. This line extends to another bus from which is tapped, through automatic oil-break switches, the circuits which supply the two step-down transformer banks. All metering is

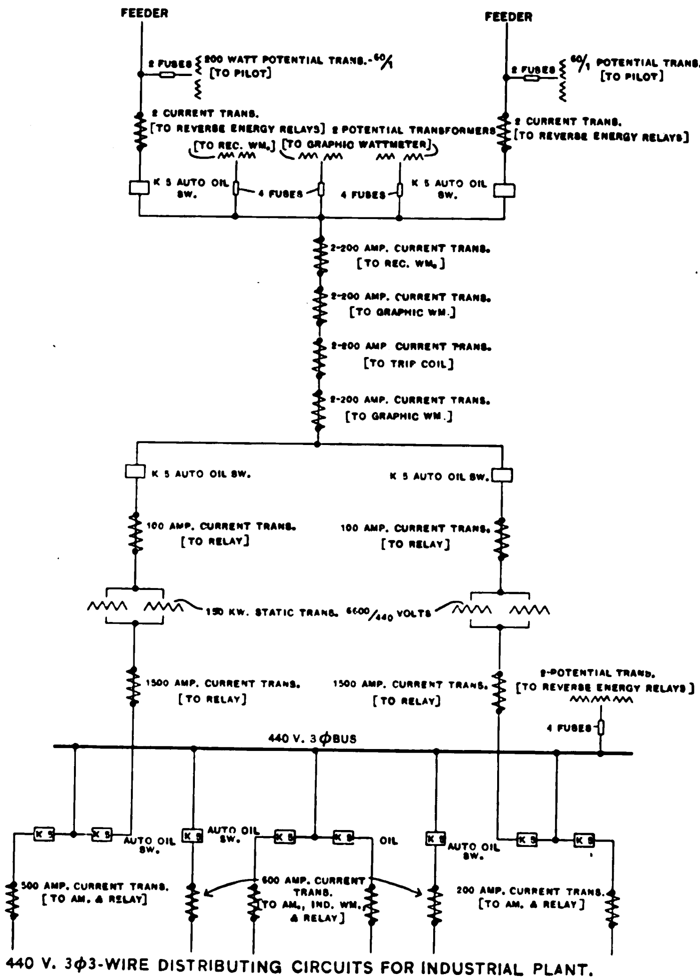

FIG. 9—ELECTRICAL CONNECTIONS OF PLANT NO. 6

done at 6600 volts three-phase, as indicated above, and the two-wattmeter method of three-phase energy measurement is employed.

The consumer's load is supplied at 440 volts three-phase taken from the low-tension side of the power transformers.

The arrangement of both high-tension and low-tension connections in the substation offers many points of interest, and, in particular, the grouping of the six 440-volt, three-phase feeders is to be noted.

Fig. 9 gives single-line diagram of substation connections, Fig. 9*a* shows interior view of substation building and equipment, and Fig. 9*b* is a detail illustration of the apparatus and wiring at rear of 6600-volt switchboard. Attention is called to the special form of porcelain fuse holder for high-voltage fuses on the potential transformers seen at top of switchboard in Fig. 9*a*. This fuse holder covers all live metal parts of the fuse clips, and so assures protection to the substation attendants.

Plant No. 7

Synchronous Converter Industrial Substation of Type Manufacturing Plant. This is supplied with 6600-volt, three-phase current through two incoming feeders.

Transforming equipment consists of two 500-kw. synchronous converters delivering direct-current energy at 240 volts three-wire to the manufacturing plant, and, in addition, two 90-kw. balancers. Total transforming capacity, 1000 kw. Number of direct-current feeders, six. Fig. 9*c* gives a general view of the substation apparatus installed in this plant.

Plant No. 8

Static Transformer Industrial Substation of Manufacturer of Rubber Goods. These goods are for the general trade, and include practically everything from belting and automobile tires down to the finest footwear and office supplies. The load at present is 1000 kw. Steady increase points to 2000 kw. within another year. The working schedule is 54 hours per week.

The consumer built his own substation and purchased all of the transforming apparatus, taking current under a high-tension contract. The operating company furnished the switch cells and switching equipment for the incoming lines, and also provided suitable metering apparatus, but, further than this, has no connection with the consumer's substation.

Energy is supplied by two 13,200-volt, 60-cycle, three-phase feeders brought to a single set of busbars through automatic oil-break switches (see Fig. 10). An electrolytic lightning arrester equipment is connected to the busbars through disconnecting switches. Potential transformers and totalizing

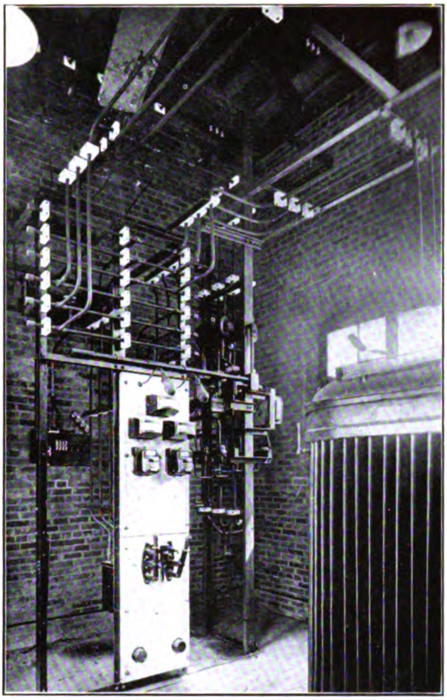

FIG. 7.—PLANT NO. 4 [LIVERSIDGE]

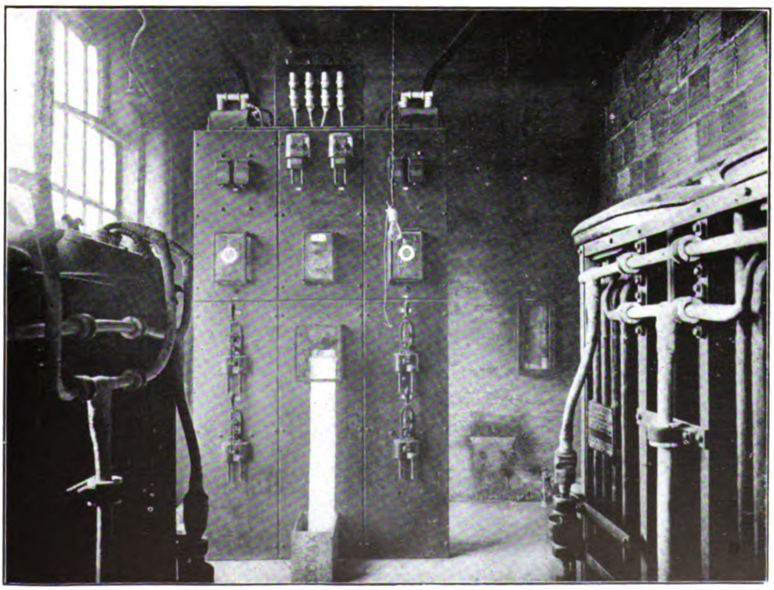

FIG. 9a.—PLANT NO. 6 [LIVERSIDGE]

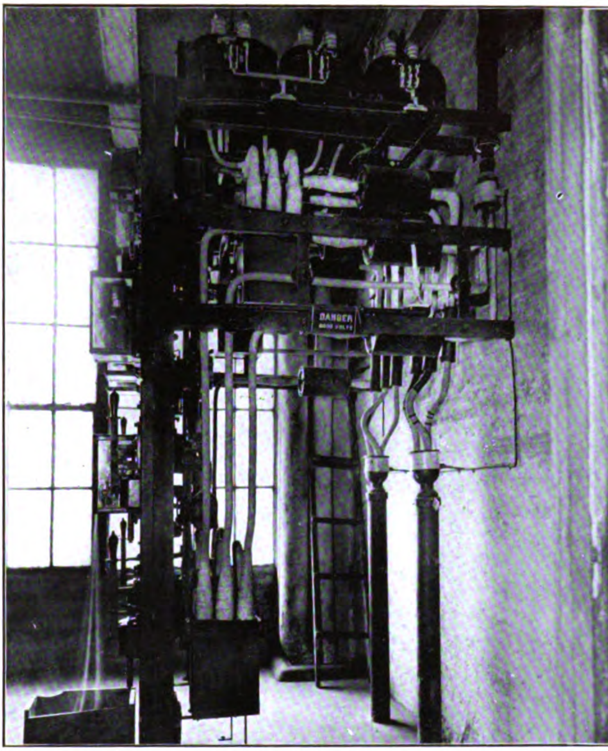

FIG. 9b.—PLANT NO. 6 [LIVERSIDGE]

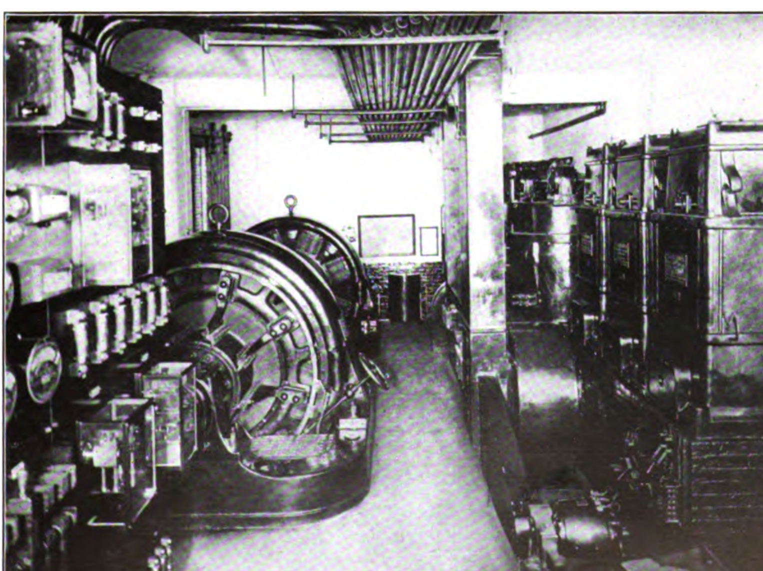

FIG. 9c.—PLANT NO. 6 [LIVERSIDGE]

current transformers are connected in the busbars and operate totalizing instruments and watt-hour meters, the two-wattmeter method being employed.

Fig. 11 gives a sectional view of the high-tension switch and busbar structure, and indicates the location of the aluminum cell lightning arrester equipment. Attention is called to the single concrete wall erected parallel to the wall of the building and furnishing the main support of the construction indicated.

The transforming equipment consists of single-phase, oil-insulated, self-cooled power transformers, of which one bank of three transformers is installed at the present time.

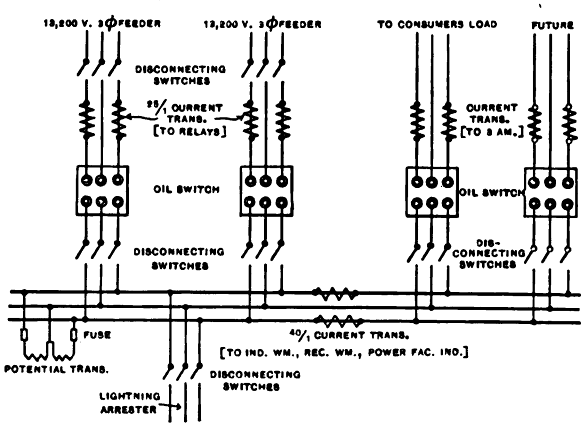

FIG. 10—ELECTRICAL CONNECTIONS TO PLANT NO. 8

Fig. 11*a* shows the general arrangement of the high-tension and low-tension switchboards, together with the transforming apparatus.

Plant No. 9

Industrial Substation Supplying Grain Elevator Equipment and Other Electrical Energy Required on Docks of Railroad Company. The total installation aggregates nearly 3000 kw., of which approximately 600 kw. is maintained exclusively for fire pumping purposes. In general, the equipment is for the operation of the grain elevator apparatus used in loading and unloading cars and for general lighting around the docks.

So far, the operating company has not had a demand in excess of 500 kw., and the hours of service are entirely dependent upon the hours of arrivals and departures of vessels and trains. The

railroad company provided the substation building and operates the station exactly as though it was an isolated plant.

The substation is supplied by three 6900-volt, three-phase incoming feeders, two of which constitute a loop into and out of the station. The loop may be closed or broken independently

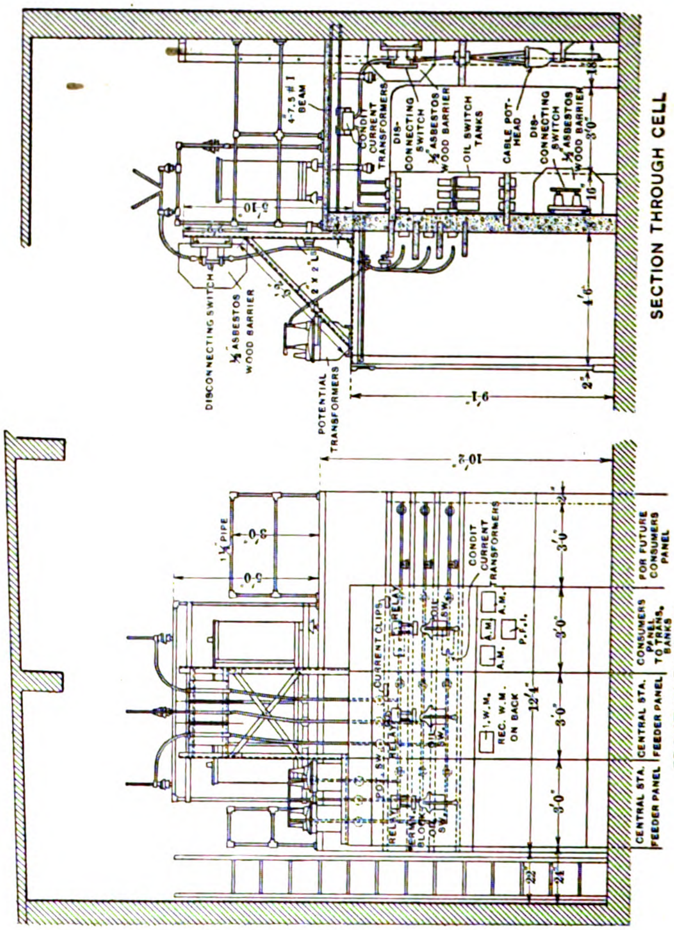

FIG. 11—CONSTRUCTION DETAILS OF HIGH-TENSION STRUCTURE, PLANT NO. 8

of the consumer's busbar by an oil-break switch connected ahead of the line-disconnecting switches of the two feeders.

Three-phase, oil-insulated, self-cooled transformers are used in this station for power service, and single-phase, oil-insulated, self-cooled transformers for lighting. Fig. 11*b* shows the exterior of the substation building, and Fig. 11*c* gives a general view of the interior.

Plant No. 10

Industrial Substation Comprising Vehicle-Charging Equipment in a City Garage. The equipment consists of one three-unit motor-generator set and three-panel control board, as shown in Fig. 12. The motor-generator set consists of one 145-kw., 120-volt, and one 45-kw., 80-volt compound-wound direct-current generator, direct-connected to a 285-h.p., 4150-volt, three-phase, 60-cycle, 900 rev. per min. synchronous motor, with a 5-kw., 125-volt, direct-connected exciter.

The switchboard equipment of the substation includes an automatic regulator used in connection with the synchronous motor and employed in order to maintain constant line potential.

The substation is supplied by a 4150-volt, three-phase, 60-cycle incoming line, feeding directly to the synchronous motor through the necessary automatic oil-break switches and starting compensators.

In order to prevent the charging set taking energy from the truck batteries, should the alternating-current supply be interrupted, the generators are equipped with reverse current relays set to operate the direct-current circuit breakers on four per cent reverse current.

Plant No. 11

Industrial Substation for Cold Storage Plant. The equipment consists of a three-unit motor-generator set embodying one 90-kw., 250-volt and one 25-kw., 250-volt shunt-wound, direct-current generator, direct-connected to a 210-kv-a., three-phase, 60-cycle, 4150-volt synchronous motor with a 5-kw., 125-volt exciter mounted directly on the end of the shaft.

The substation is supplied by one 4150-volt incoming feeder on which are installed electrolytic lightning arresters and choke coils. The feeder is taken directly to the synchronous motor through the necessary automatic oil-break switches and a three-phase starting compensator for the motor. The motor is equipped with an automatic voltage regulator in order to insure constant line potential.

In this installation it has been deemed advisable to protect the direct-current generator circuits by fuses only, instead of by the usual automatic overload circuit breakers.

The attendance at the plant is good and, while the voltage regulator has given some trouble, the operation of the plant is satisfactory. The load for this class of refrigerating service is very constant throughout the twenty-four hours.

Fig. 13 shows the switchboard at this plant, and one end of the motor-generator set, and indicates the extreme simplicity of the electrical equipment installed.

Plant No. 12

Combination of Synchronous Motor Pumping Station and Small Synchronous Converter Substation: Shown in Fig. 14.

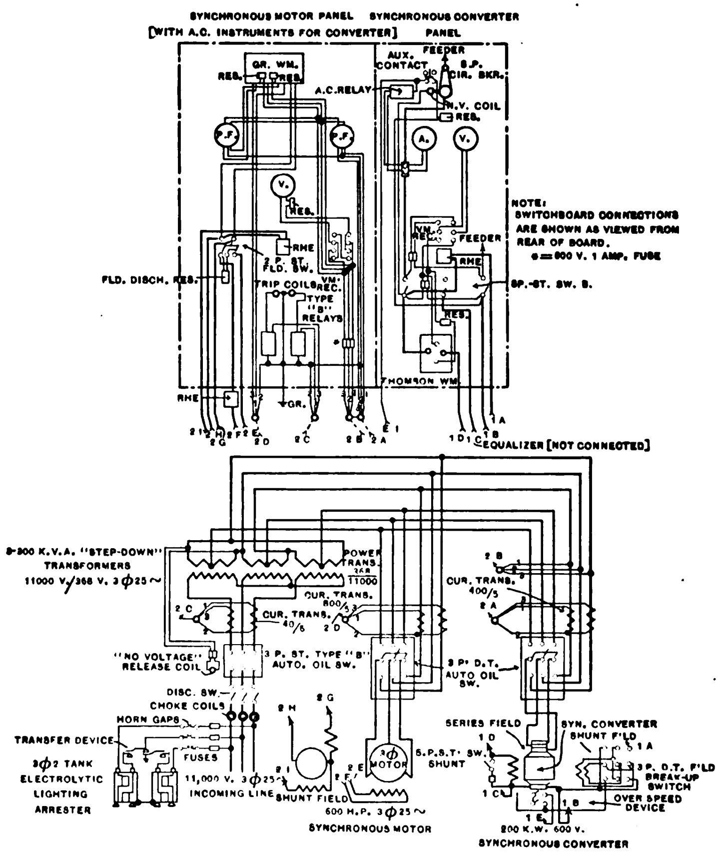

FIG. 15—DETAIL ELECTRICAL CONNECTIONS FOR PLANT NO. 12

This equipment consists of a 600-h.p. pump motor (6,000,000-gallon high efficiency pump) and a 200-kw. 600-volt railway synchronous converter which feeds a suburban trolley line. The total capacity is approximately 700 kw. Current is supplied at 11,000 volts, three-phase, 25-cycles, on one incoming feeder entering the substation overhead. The feeder is taken

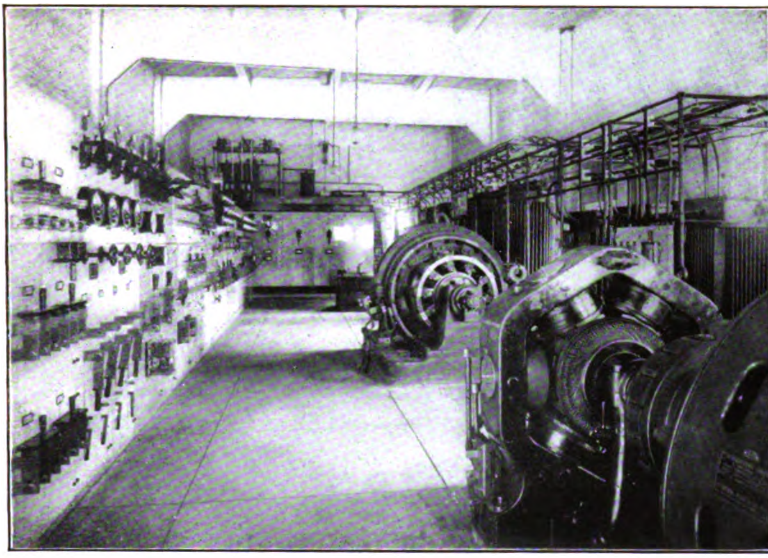

FIG. 11*a*.—PLANT NO. 8 [LIVERSIDGE]

FIG. 11*b*.—PLANT NO. 9 [LIVERSIDGE]

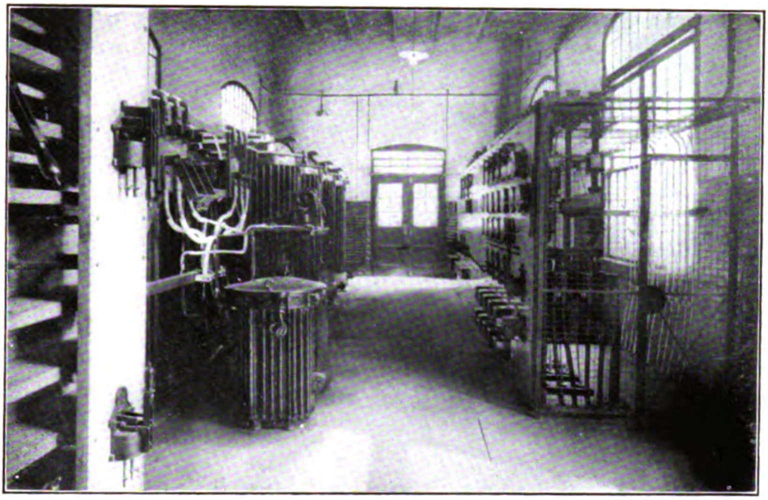

FIG. 11c.—PLANT NO. 9 [LIVERSIDGE]

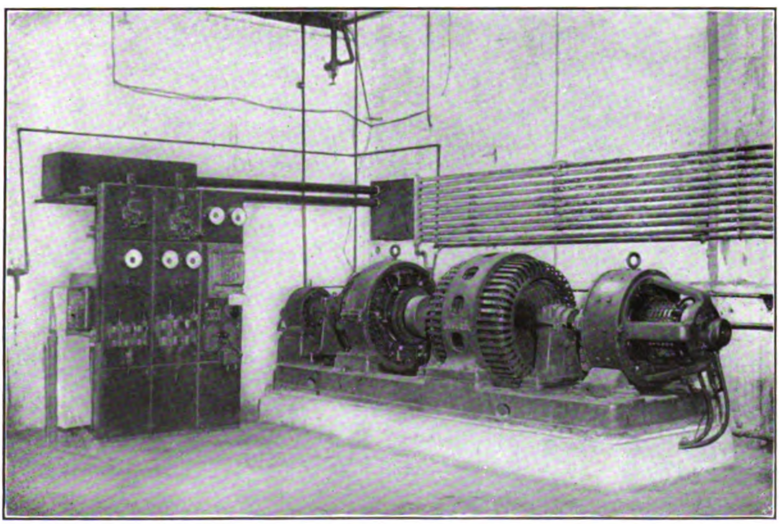

FIG. 12.—PLANT NO. 10 [LIVERSIDGE]

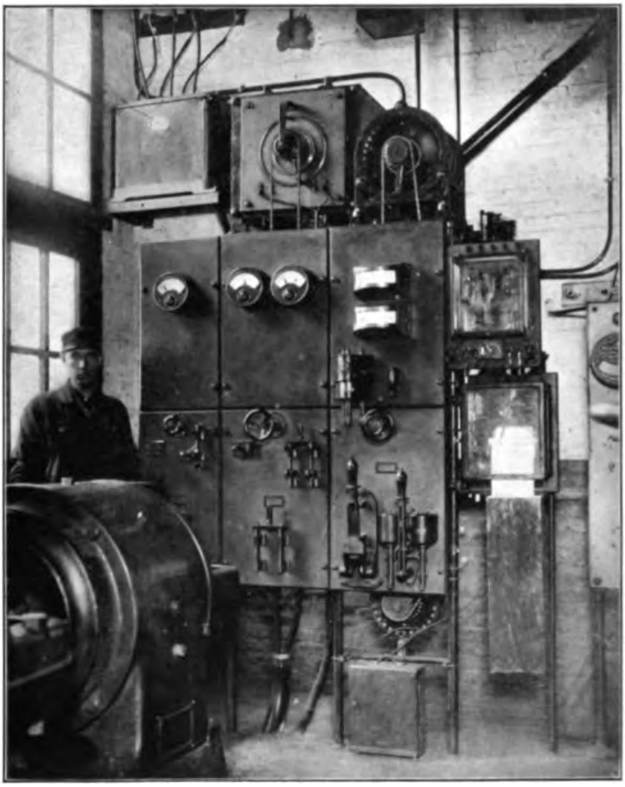

FIG. 13.—PLANT NO. 11 [LIVERSIDGE]

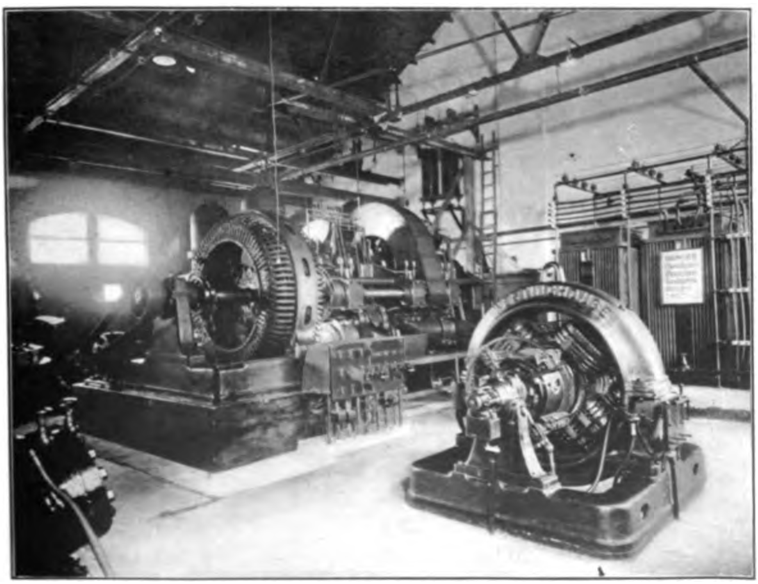

FIG. 14.—PLANT NO. 12 [LIVERSIDGE

through an oil-break switch, equipped with no-voltage release, directly to a bank of three single-phase step-down transformers which on the low-tension side (368 volts) supply *both* the 600-h.p., three-phase motor and the 200-kw., three-phase synchronous converter.

Both motor and converter are alternating-current starting, from reduced voltage taps on the transformers. A spare transformer unit is maintained in readiness for emergency service. Under agreement between the operating company and the consumer, the operation of the synchronous converter is attended to by the consumer.

The accompanying diagram, Fig. 15, gives the detail connections of the substation equipment.

* * * *

In the descriptions of industrial substations given above, attention has been called particularly to the more important characteristics of design and general construction. At this point it will be interesting to undertake further analysis of those details which have a direct bearing upon the factors to which attention has already been called in the early part of the paper.

These factors may be enumerated again: (1) Space economy; (2) Operating requirements; (3) Fire hazard and safety to attendants; and (4) Cost.

1. *Space Economy.* In all instances this factor should be given careful consideration. Especially is this true when the equipment is to be installed in an already existing factory building, where the consumer has allotted all the space available, and this space permits no latitude in the arrangement of equipment.

Plant No. 3, a synchronous converter substation of four 300-kw. units, is a striking example of the economy which has been effected in this particular. The space provided for the equipment was one corner of an existing engine room which already contained several engine-driven generators, a heavy duty air compressor, and other miscellaneous power plant auxiliaries. The floor area allotted to the substation equipment measures approximately 30 ft. by 30 ft. (9.14 by 9.14 m.). The height of the engine room permitted the construction of a short gallery upon which was placed all high-tension switching and protective apparatus. This arrangement, while it might not have been selected had a new substation building been erected, neverthe-

less made possible the installation of all apparatus without necessitating any changes in the building construction.

Again, Plant No. 1, which is a static transformer substation, illustrates very clearly the great economies of space to be effected by proper arrangement of the switching and transforming equipment, without impairing, in any way, the efficiency of the design.

Plant No. 10 is also an illustration of an exceedingly compact arrangement of electrical apparatus. In this installation a 285-h.p. motor-generator set and the control switchboard are placed close to the wall of the building. No additional housing was provided in this instance, thereby securing a limited floor area for the installation.

2. *Operating Requirements.* The conditions under which the various equipments of substations operate are often radically different, due to the requirements of the consumer. Careful consideration should be given this point.

One of the important features relating directly to this question is the duration of continuous service, which may vary from a few hours per day to a practically continuous supply. As due provision must be made for inspection and repairs, it is quite evident that, in the case of continuous operation, attention must be given to the proper sectionalization of the apparatus and duplication of equipment. This is indicated in the design of Plant No. 1, Fig. 1. In this case, each individual circuit controlling the incoming feeders and transformer banks is provided with disconnecting switches.

As previously noted, this plant operates almost continuously, and such an arrangement permits of a ready examination of the operating equipment during light loads, without necessitating the interruption of the consumer's service. This type of construction further permits a comparatively simple installation, and obviates the necessity of a duplicate set of busbars and oil-break switch equipment.

In contradistinction to this lay-out, Plant No. 2, Fig. 3, supplying a very intermittent service, is arranged without any means for sectionalization. Provision only is made for disconnecting the single incoming high-voltage feeder from the substation equipment.

Another point to be considered in connection with this question is the operating attention which will be given the installation, either by the consumer or the central station company.

In most cases, however, it is the desire of the consumer to supervise the operation of his equipment, and as a rule this plan is productive of satisfactory results.

It is evident, therefore, that any complications in switching equipment and control apparatus should be studiously avoided.

3. *Fire Hazard and Safety to Attendants.* In connection with this feature, it is interesting to note the tendency toward particular care in construction details as they relate directly to this subject.

Where substation apparatus is to be installed in existing industrial plants, a considerable amount of reconstruction is sometimes advisable. In many cases, the floors and ceilings of the industrial buildings are wood. These should be made fireproof. The usual building alterations consist of the changing to concrete flooring and metal-lined or asbestos-covered ceilings.

In oil-cooled transformer installations, special arrangements are necessary for properly draining the contained oil from the transformer cases. This is accomplished either by pipes connected directly to the transformers or by concrete drains built in the transformer foundations and connected to a common outlet.

An interesting example of this latter type of construction is noted in Plant No. 5, Fig. 8. In this installation, the transformer banks are placed on a concrete base so constructed as to provide a very effectual drainage system for the entire equipment.

The enclosing of high-voltage switchboard equipment to secure the *maximum* of safety to attendants is plainly evidenced in the plant designs to which attention has been called. Asbestos lumber doors and partitions form the more important part of this detail in construction. Besides serving as a protection from accidental contact with high-voltage circuits, these partitions in many cases are excellent barriers for protection from fire.

Plants No. 1, Fig. 2, No. 3, Fig. 4 and No. 8, Fig. 11 may be cited as typifying this feature of construction. A particularly interesting example may be noted in Plant No. 1, Fig. 2, where the high-voltage equipment is entirely enclosed and cannot be reached except by the opening of the several doors composing the enclosing partitions.

4. *Cost.* Not infrequently the central station engineer is limited to a certain minimum expenditure imposed by the prospective consumer, and which in most cases affects the electrical equipment under consideration. It is evident that this limitation may

affect materially the character of the installation; and particularly will this be evidenced in the switchboard and controlling equipment. The changes in this part of the construction are most apparent in the details of control equipment, namely, the type of switchboard, whether marble, slate or open iron frame; the number and type of instruments on the individual circuits, and the character of busbar construction.

These details in many cases are closely related to, and influenced by, the factors already noted.

Nevertheless, there are many points in the design, as above mentioned, that will be directly influenced by the question of construction cost.

Conclusion. In the present paper, all detail references to costs, and to the economic questions involved in the subject of industrial substations, have been purposely omitted. Furthermore, in the discussion of the plants presented the writer has refrained from all criticism which relates to the question of efficiency in station design.

The attempt has been made, rather, to emphasize how well the engineering design and installation of substations located in consumers' premises, and receiving electrical energy from a central station system, meet the most varied and exacting requirements of the industrial consumer.

* * *

The writer wishes to take this opportunity to express his appreciation of the courtesies shown by the engineering departments of the Commonwealth Edison Company, the Edison Electric Illuminating Company of Boston, the Edison Electric Illuminating Company of Brooklyn, the Rochester Railway & Light Company, and the Philadelphia Electric Company; also to acknowledge the able assistance of Mr. Charles Penrose and Mr. H. C. Albrecht, both of the engineering department of the Philadelphia Electric Company, in the compilation of the paper.

DYNAMO ELECTRIC LIGHTING FOR MOTOR CARS

BY

ALFRED E. WALLER

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Abstract of Paper

The design of motor car lighting apparatus begins with the choice of a satisfactory lamp equipment. This fixes the quantity of energy which the lighting system must supply at any time, and indicates the dynamo capacity to be provided.

The dynamo must be geared to give its full output at the average speed reached when driving, with all lights on, in order that the battery reserve may be drawn upon only when the car is not in motion.

When a battery auxiliary is used it must be connected to the dynamo when conditions are right for charging, and disconnected when the engine is at rest, to prevent discharge through the dynamo. Safety and convenience require that this action should be automatic, also that the output of the dynamo should be limited to a predetermined and safe maximum, regardless of dynamo speed. This leads to a discussion of methods devised to secure automatic control, and to the speed rating of the dynamo itself.

This is limited on one hand by the weight, size and cost of slow-speed dynamos, and on the other, by consideration of wear on bearings, commutator and driving means of the high-speed type.

Following this are notes on storage battery capacity, and wiring.

A paper to be presented at the 288th Meeting of the American Institute of Electrical Engineers, New York, November 14, 1913.

DYNAMO ELECTRIC LIGHTING FOR MOTOR CARS

BY ALFRED E. WALLER

Dynamo lighting equipments on motor cars are required to maintain at all times a supply of electric energy sufficient for proper road lighting. It is therefore natural, in the design of such apparatus, to decide first what may be accepted as a satisfactory set of lamps for motor car use. When this point has been determined, the capacity of dynamo, battery, and auxiliary apparatus may be readily deduced.

The choice of lamps is influenced by a great many considerations, and, among these is the variable element of individual preference. Some drivers prefer to have a good deal of light near the car, others insist upon lamps which will project the light a considerable distance ahead, and leave objects close at hand in comparative darkness. Many arguments are offered in favor of each type, and, in order to have his product meet with general favor, a lamp designer must take both extremes into account.

A great deal of interesting experimental work has been done with headlights of both American and foreign design, in order to determine the characteristics of the most suitable lamp and reflector.

As a result the 21-c.p. six-volt tungsten lamp has been adopted for use with a parabolic reflector measuring 10 in. (25.4 cm.) across the opening.

This choice was governed by several considerations. In the first place it was shown that with lamps of this description a road 50 ft. (15.2 m.) wide could be perfectly lighted for a distance of at least 1000 ft. (304.8 m.) in advance of the car. Objects on the road could be distinguished practically as far away as

would be possible in day light, and always in ample time to stop or turn aside as the case rendered necessary.

In the second place, 10-in. (25.4 cm.) reflectors were used because they did not necessitate extremely large headlights, which, beside being costly, would detract from the appearance of a motor car. The importance of having lamps properly focused was brought out in these experiments. For the best results the lamp filament must be located exactly at the focus of the parabolic reflector, and the reflector should be so designed, that the focus is well back from the opening. A comparatively deep reflector makes the angle of the direct rays not intercepted by it, rather small, consequently a greater proportion of the total candle power may be projected in a useful direction. The effect is particularly good when the lights are placed at least three ft. (0.9 m.) from the ground. At this height the shadows caused by slight ridges and undulations in the road, are not so apparent as when the lights are placed lower.

The 10-in. (2.54 cm.) parabolic reflector adopted, measures about 5½ in. (14 cm.) in depth. This reflector has a focus of 1⅛ in. (2.85 cm.) and, when properly focused, a 21-c.p. lamp gives ample light on the road near the car and at the same time has very good distance qualities.

Very deep reflectors both of the eight in. (20.3 cm.) and 10-in. (25.4 cm.) diameter sizes were tried, but it was found that these did not give satisfactory lighting near the car.

Twenty-four c.p. lamps were tried out in the 10-in. (25.4 cm.) reflector, but the difference in illumination was scarcely noticeable, and was more than offset by the fact that the 24-c.p. lamps required 14 per cent more current than the 21-c.p.

The side and rear lights, which are used only as signal lights, and have little value for road lighting purposes, were equipped with four-c.p. and two-c.p. lamps respectively. Lights of lower candle power than this would have been ample for the purpose, but in the smaller sizes of lamps the filaments were found to be too frail to give reliable service under the conditions of severe vibration encountered on a motor car.

Considering therefore that a proper equipment consists of a pair of 21-c.p. headlights, a pair of four-c.p. side lights, and a two-c.p. rear light, we find the current taken by these lamps to be seven amperes, 1.7 amperes and 0.6 amperes respectively, making a total load of 9.3 amperes at 6 volts. In addition to this equipment we find on the average car an electric horn and

a speedometer light, but as these devices are used only intermittently, their current is not an important factor in determining the maximum dynamo capacity which will be required.

Allowing for the intermittent use of the speedometer light and electric horn, it is evident from the figures quoted above, that an adequate lighting dynamo must have an output of 10 amperes, in order to maintain at all times a sufficient supply of energy. Further, as the dynamo is available as a source of energy only when the motor car engine is running, a battery must be provided to furnish current when the engine is at rest. A three-cell lead battery has been universally adopted for use with 6-volt lights, and the dynamo must therefore be capable of furnishing 10 amperes at a voltage sufficient to charge a battery of this type.

Our next consideration is the car speed at which the full load output of the dynamo must be delivered. Much of the mileage covered by the average motorist is traversed at a speed of not more than 18 miles per hour and if we are to reserve the storage battery for use when the motor car engine is not running our dynamo must be so geared that it will carry the entire light load when the car is traveling at this speed or above. If the speed falls below say 18 miles per hour, more or less current will be drawn from the battery, as the dynamo will not be generating its full capacity. A great deal of night driving at slow speed with all lights on, would in time run down the storage battery, but it is found in practise that little slow-speed running is done with all lights on. In the city where this condition does prevail to a large extent, the headlights are not as a rule in use, and the load taken by the remainder of the equipment is readily supplied by the dynamo. Further, if the car is used in the day time at all, the charge accumulated by this running serves to keep the battery always charged and in perfect condition. If cars are left standing, the headlights are of course turned off and the 2.3 ampere load represented by the side and rear lights may be carried for some time upon a proper battery.

The ideal electric lighting system is entirely automatic. Means must be provided for connecting the dynamo to the battery when speed proper for charging has been reached, and for disconnecting the dynamo from the battery when the speed is reduced to a point where a reversal of current is about to take place. This is a feature which is present in all properly designed lighting systems.

In some systems now on the market, the connecting and disconnecting from the battery is accomplished by a centrifugally operated switch. The dynamo speed which corresponds to a correct voltage for charging is predetermined, and the centrifugal device is set to close the circuit at this time, and to open it as soon as the speed is reduced below the safe point. In most cases, however, the operation is accomplished by means of an electromagnetic switch. This switch or relay, as commonly constructed, has two windings, one of high resistance which is permanently connected across the armature terminals. The relay is set so that it closes the circuit between the dynamo and the battery, when energized by a potential sufficient for charging the battery, and opens the circuit when the dynamo voltage is reduced below this point. As a precautionary measure, a series winding is placed upon the relay with the shunt winding. This series winding reenforces the shunt winding while charging is going on, but bucks it upon reversal of current, thus tending to produce complete demagnetization of the relay.

One of the most important functions of the automatic lighting system is the control of the dynamo output at the very high speeds reached by motor car engines. It will be readily understood that if a dynamo is arranged so that it is driven at say 1000 rev. per min. at a car speed of 20 miles (32 km.) per hour, and is delivering its full output at this speed, when the car speed has been increased to 40 miles (64.3 km.) or even 60 miles (96.5 km.) per hour, a dynamo not properly protected will be forced to generate current far in excess of its rated capacity and a burn-out will inevitably result. No matter what type of dynamo is used, there must be some means of compensating for the current fluctuations which occur with speed changes.

As in the case of the automatic switch for connecting to the battery, the more difficult problem of controlling dynamo output has been accomplished by means of both mechanical and electrical devices. It is my intention in this paper merely to describe a number of regulators which are now widely used without commenting either favorably or unfavorably upon their respective merits.

Considering first the mechanical types of control, we have slipping clutches of different designs. For example, one manufacturer uses a clutch composed of two members, one of which is rigidly attached to the dynamo shaft, and the other to some convenient drive shaft. The clutch members are held together

by spring pressure, and, as the speed of the driving member increases, this spring pressure is neutralized by means of centrifugal governors, which oppose the spring tension, and allow slippage between the clutch members, the amount of slippage depending upon the speed of the driving member. This allows the dynamo to be given at a substantially constant speed, regardless of that of the motor car.

The regulator adopted by another manufacturer has in it a centrifugal governor which turns at the same speed as the dynamo, and moves a small contact arm over a number of steps of resistance inserted in the field circuit of the dynamo. The greater the dynamo speed, the more resistance is inserted with the field, so that a substantially constant output is obtained.

There is a much larger number of electrical devices for this purpose. One of the earliest consisted of a resistance made of small carbon discs arranged in a tube and connected in series with the dynamo field winding. The disks are normally pressed very tightly together by a spring, and in this condition have a low electrical resistance. The device is so arranged that the armature current if the dynamo passes through a series coil, which is arranged to pull directly against the spring which compresses the carbon disks. Consequently when excessive charging rates are reached, the pull of the series coil tends to neutralize the spring pressure upon the carbon disks, and the resistance of the field circuit is increased by the release of pressure.

One method which is much used with the permanent field type of dynamo is to design a machine with high armature reactions, and to depend upon these to prevent excessive generation of current. Compound windings have been successfully used with both bipolar and multipolar dynamos for this work, in spite of the very great range of speed encountered.

Other manufacturers have used double field windings, one portion arranged to opppose the flux generated by the other portion. These opposing or bucking coils are thrown into play at the proper moment by a series relay inserted in the armature circuit.

One magneto type dynamo manufactured has a permanent field with auxiliary electromagnetic field windings, which are disconnected when a certain current has been reached. If the speed is increased beyond this point, the auxiliary electromagnetic fields are again brought into play and are energized so as to oppose the flux of the permanent field. This gives a very wide range of regulation.

In several cases, modifications of the controls described above have been used by regulating the dynamo for a certain maximum voltage instead of maximum current.

In another lighting system regulation is accomplished by the introduction of a coil of iron wire in the armature circuit. This coil has the property of increasing resistance very slowly, until a certain critical current is reached, and then increasing at a very rapid rate to several times its original resistance. The terminals of a bucking field coil are connected across this series coil of iron wire, which is so designed that the critical point where its resistance increases rapidly, is reached when the maximum dynamo current is being generated. Normally the potential difference applied to the terminals of the bucking coil, is negligible, but when the iron wire has become sufficiently heated, this potential difference becomes sufficient to generate a considerable flux in the bucking coil, and to reduce materially the output of the dynamo.

Among the devices designed to secure constant dynamo output at varying speeds, are several foreign inventions. In one of these a bipolar shunt wound dynamo is arranged with a pair of auxiliary poles placed between the main poles of the machine. The auxiliary poles are not wound, but are excited by the cross magnetization caused by the working current in the dynamo armature. Two brushes are placed in the neutral position relative to the main poles, and are sufficiently wide to short circuit several armature coils during the period of commutation. When the armature is revolved the dynamo behaves as any ordinary shunt-wound machine, except that the load current in the armature conductors, by virtue of its cross magnetizing ampere turns, sets up a flux in the auxiliary unwound poles, provided to receive it. The armature coils short circuited by the brushes cut this cross flux and consequently have a short-circuit current induced in them, which is proportional to the cross flux and to the speed of rotation. This short-circuit current acts in such a direction as to demagnetize the main wound poles. In this manner the voltage of the dynamo is regulated so as to compensate for speed changes and also for load changes.

One foreign manufacturer has designed a distributing panel, in which each circuit on the car has a properly proportional coil of resistance wire in series with it. This wire is of such gauge and length that it permits a certain amount of current

to flow in the circuit, this being predetermined, and increases in resistance to eight or ten times its nominal value when this current value is exceeded, thus protecting the lamps against burn out.

In a well known French design a bipolar dynamo is used, with two windings on each pole, the pairs being wound to produce magnetization in the same direction. One side of each of the four coils is connected to the negative brush of the dynamo, and the four remaining terminals are connected to the positive brush, through four small breakers arranged concentrically around the dynamo shaft. These breakers are opened in succession by a cam on the end of the dynamo shaft, and only one breaker is opened at a time. At slow speeds the effect produced by opening momentarily one of the four field coils and closing it again before opening another, is negligible, but as the speed is increased the interruptions become so rapid that the dynamo field does not have time to build up to its full intensity and constant output may be secured from the dynamo over a wide speed range.

In the particular lighting system under consideration a plain shunt-wound dynamo was adopted as being the simplest and most reliable type, and a system of control was developed which gives perfectly satisfactory regulation. The necessary regulation is secured by means of a single step of resistance inserted in series with the dynamo field. This resistance, which is of such a value that it will limit the dynamo output to its predetermined maximum at the highest car speed obtainable, is normally short circuited, but the short circuit is removed from the resistance when the maximum charging current has been reached. This is accomplished by means of a relay, the coils of which carries the armature current. In practise, the short circuit is removed from the resistance in series with the dynamo field when a current of 10.1 amperes has been reached, and when this resistance is thus inserted in the field circuit, the dynamo output immediately falls off. When the current is reduced to 9.9 amperes, the resistance is once more short-circuited, and, as the interval of time required for this change in current is very short, an extremely rapid vibration of the relay contact is set up, and a substantially constant current is obtained over a wide range of speed.

In the early experimenting, a relay of the familiar telegraph type was used, but lengthy experiments led to the adoption

of a modified type in which the trunnions or pivots are replaced by a flexible phosphor-bronze hinge of suitable gage and width. This construction is found to be highly satisfactory, and is not affected by vibration.

There are a number of other systems of control which are quite as efficient and well known as these I have mentioned, and a great deal of time might be devoted to their discussion and comparison. It is necessary at this time, however, to consider the initial speed at which a dynamo should be designed to give its full output. This is an important consideration, and is so closely related to the construction of the motor car engine with which the system is to be used, that the general arrangement of the engine must be carefully taken into account.

It is well known that the size, weight and cost of a dynamo of any particular type, depends not only upon the watt output, but also upon the speed at which this output is delivered. Consider as an example the shunt wound dynamo; one which will deliver 7.5 volts and 10 amperes at 1500 rev. per min., costs 30 per cent less than one which will deliver the same output at 1000 rev. per min., and less than half as much as one designed for a speed of 500 rev. per min. The weights of the respective machines are in approximately the same ratio as their cost.

A shunt-wound dynamo designed for the stated output at approximately 1000 rev. per min. weighs about 21 lb. (9.5 kg.) and can be made approximately 8 in. (20.3 cm.) long by 5⅝ in. (13.2 cm.)high by 4¾ in. (12 cm.) wide. If it is required to secure the same output at 500 rev. per min. the weight must be increased to approximately 35 lb. (15.8 kg.) and the dimensions become 9¼ in. (23.5 cm.) by 7½ in. (18 cm.) by 4¾ in. (12 cm.) approximately. On the average four-cylinder motor car, a 1000-revolution dynamo is run at about twice engine speed for the best results, and the 500-revolution dynamo should be run at engine speed.

Bearing these facts in mind, the selection of a dynamo for any particular automobile engine becomes a matter of judgment and must be largely governed by the structure and arrangement of the engine itself. Speaking broadly, it will be found that when a 500-rev. per min. dynamo may be readily coupled to a shaft which runs at engine speed, its extra weight and cost are justified by the fact that it renders sprockets and chain or gears, and their care, unnecessary. On motors where an installation of this type entails the extension of a shaft

not readily accessible, or the use of a countershaft or an idler gear or some other device for bringing the direct drive into a convenient location, a chain driven dynamo geared to run at twice engine speed may be used to advantage.

Where a geared dynamo is necessary, the shunt-wound machine designed to deliver its output at 1000 rev. per min. and driven at approximately twice engine speed, appears to be the most advantageous design in weight, cost and size. Such a dynamo when driven at twice engine speed on a car with 36-in. (0.9 m.) rear wheels, geared 3½ to 1 on the back axle, will start charging the battery at from six to seven miles (9.6 to 11.2 km.) per hour, and will deliver its full output of 10 amperes at about 15 miles (24.1 km.) per hour. The same dynamo on a car geared 3 to 1 with 36 in. (0.9 m.) rear wheels, would begin to charge the battery at approximately 9 miles (14.4 km.) per hour, and will balance the lamp load at approximately 18 miles (28.9 km.) per hour. A machine of this type has distinct points of advantage over a dynamo designed to deliver its output at either a higher or a lower speed.

Considering first a higher speed dynamo, let us assume a rated speed of 1500 rev. per min. for full output. This dynamo is smaller, lighter and cheaper than a dynamo designed for 1000 rev. per min., but must be driven at approximately three times engine speed. In practise if a ⅜-in. (9.5 mm.) pitch silent chain is used, the driven and driving sprockets will have 15 and 45 teeth respectively. This means a chain speed of 2250 ft. (685.8 m.) per minute at 45 miles (72.4 km.) per hour of the car and 3000 ft. (914.4 m.) per minute at 60 miles (96.5 km.) per hour. These speeds are too high for best results and cause rapid wear of the chain. It should be noted also that the chain is likely to become noisy when driven at this speed.

On the other hand, a dynamo driven at less than twice engine speed, in order to secure lower chain speed, and less wear on the bearings, is not an advantageous arrangement. The cost and weight of the dynamo are immediately increased without the elimination of sprockets.

It becomes evident therefore that if the chain speed reached by the drive of the 1000-rev. per min. dynamo is not excessive, it has a decided advantage over either of the types just mentioned. Investigation shows that in practise sprockets of 30 and 15 teeth would be used with ⅜-in. (9.5 mm.) pitch silent chain, and at 45 miles (72.4 km.) per hour the chain speed would

be 1500 ft. (457.2 m.) per minute, and at 60 miles (96.5 km.) per hour it would run 2000 ft. (609.6 m.) per minute. These speeds are not excessive and are within the limits of the speed at which a chain may be used with best efficiency.

The problem of driving dynamos on different types of motor car engines is capable of many solutions. In some cases it is possible to secure a direct drive at engine speed, through an Oldham coupling, and this is an instance in which the slow-speed dynamo may be used to great advantage. In many cases it is possible to extend the pump shaft back through the pump casing, and to obtain a direct connection in this manner. In other instances it has been possible to move the magneto and to install in the place formerly occupied by it a dynamo with a double-end shaft, to which the magneto is afterwards connected by means of an Oldham coupling, and the two units driven in tandem fashion. This arrangement on a six-cylinder car requires a dynamo wound to deliver its output at 1½ times engine speed, that is about 750 rev. per min.

With the 1000-rev. per min. dynamo, drive may be secured by means of a sprocket installed on the pump or magneto shaft, a sprocket on an extended half-time shaft, or one fastened to the crank shaft directly back of the clutch which engages the starting handle. In other installations it is possible to drive by a gear, meshing with one of the timing gears, or with one of those in the transmission. Either of these last methods make a very satisfactory installation where they can be used, as the gears, encased and running in oil, are almost absolutely noiseless.

All of these methods and numerous others have been tried out and shown to be entirely satisfactory, both as regards noiseless operation and life.

The remaining points to be considered are the size and capacity of battery to be used, and the method of wiring.

In order to meet satisfactorily the severe conditions to which it is apt to be subjected, the battery must have plates sufficiently large to stand charging at the maximum dynamo output for an indefinite time, without deterioration. This condition would be imposed upon it by an automobile owner who drives only in the day time. It should have sufficient capacity to maintain all lights on the car for six hours, and to carry the side and rear lights only, for from 20 to 24 hours, without receiving any charge.

Exhaustive experiments have demonstrated that a battery with 160 sq. in. (852.3 sq. cm.) or more of positive plate surface

and 100 sq. in. (645.2 sq. cm.) of negative plate surface, is capable of standing a 10-ampere charging rate for very long periods, even when no current is taken from it. It is unquestionably possible to damage a battery of the above size by charging at a 10-ampere rate, if carried on indefinitely on a test bench. The condition of motor car service, however, tend to offset the main causes of deterioration which become noticeable when the batteries are charged at high rates. In the first place a battery charged continuously at a high rate becomes overheated, and this heat softens the plates to such an extent that they are readily disintegrated. Another cause of decay is the formation of large bubbles of gas on the negative plates, which when they finally break away from the plates, take with them particles of active material, especially when this has become softened due to heating.

The chance of overheating a battery due to continuous high charging rates, becomes rather small when we consider that it is seldom, in practise, that a battery is charged continuously at the maximum rate for more than a few hours at a time. It is seldom indeed that a dynamo in motor car service delivers its full output for several hours at a time without intermission, because automobiles are rarely driven at a continuous speed of 18 miles (28.9 km.) per hour or above for long intervals. In addition to the frequent slowing down of the motor car engine, due to coasting down hill, or turning corners, there are often periods when it is not running or is running slowly, so that the dynamo does not generate its maximum current. It has been proved in practice that in the average installation no appreciable heating takes place, and that even the drivers who maintain the highest average speed never raise their batteries to an excessive temperature. Referring to the second cause for deterioration, it will be evident that the vibration always present in motor car service, makes practically impossible to form large bubbles upon the battery plates. The jolting of the automobile becomes practically a substitute for the mechanical agitator which is used in many large stationary battery plants.

A battery installed on the average motor car is operating under ideal conditions, as it is either charging or discharging nearly all the time. If the plate surface mentioned above is used, the 9½-ampere load represented by the total light equipment may be carried for approximately 3¼ hours, while the side and rear lights may be kept bright for at least 24 hours. It will be ap-

parent that the 3¼-hour limit for the length of time during which the battery will take care of the entire load, is hardly long enough, so that a battery used in a motor car equipment, should have approximately double the capacity given, or approximately 80 ampere hours. In a very large number of lighting systems now operating successfully, standard makes of batteries rated at 80 ampere hours with a 10-ampere discharge rate, are proving entirely adequate. A battery of this type has considerably more than the necessary plate area to stand the 10-ampere charging rate indefinitely, and will carry all lamps for at least six hours, a longer time than would be ordinarily required.

The remaining point now to be considered is the method of wiring, and type of wire used. In many of the first lighting systems, the proposition of a ground return for all fixtures was pointed out, but in practically all instances the system of running two wires to each lamp and fixture has been adopted. Ground returns in many cases brought about ignition complications, and the system of two wires has a decided advantage in that one conductor may be grounded accidently without interfering with the lights. On the ground return system an abrasion or injury to the current-carrying wire is apt to put the entire system out of operation. In a recommendation to a special advisory committee of the Society of Automobile Engineers, Mr. Leonard Kebler, a member of the Society, proposed that for motor car installation, a cable be used capable of standing a test of 12 hours immersion in oil, 12 hours immersion in gasolene, and 12 hours immersion in water, and then stand 500 volts applied between the two conductors without a breakdown. Wire of this type has been used extensively by several manufacturers and has been found to give excellent results.

The insulation of wire for motor car use, should be composed preferably of some material which is not affected by oil or gasolene, and is not softened by ordinary temperatures. Where rubber is used it should be protected against oil and gasolene to prevent the possibility of grounds and short circuits.

In concluding, it may be said of the lighting system wiring that the manufacturer should, if possible, cut all wires to length and make all connections before shipment. Experience proves that the highest satisfaction with motor car lighting equipments may be obtained only when the wiring is done by skilled operators. Consequently, a lighting system designed

in such a manner that it may be purchased for any particular make or model of car, with all wires cut to length and fitted with proper plugs, all connections made to panels, switches, etc., possesses distinct advantages. The work of installation is reduced practically to fastening the switch, controlling panel, battery, and dynamo to the car. It has been found possible to arrange lighting systems in such a manner that the only connections which need to be made by the user, are those between the system of wiring and the dynamo, and also to the battery terminals.

By arranging the dynamo connections with different sizes of binding posts, so that the wires cannot be put on in wrong order, and treating the battery binding posts in the same manner, the chances of trouble due to improper wiring are reduced to a minimum, and satisfaction is secured from the point of view, both of the manufacturer and the automobile owner.

ADVANTAGES OF CLUTCH TYPE GENERATOR AND SEPARATE STARTING AND LIGHTING UNITS FOR MOTOR CARS

BY

ALEXANDER CHURCHWARD

1987

ADVANTAGES OF CLUTCH-TYPE GENERATOR AND SEPARATE STARTING AND LIGHTING UNITS FOR MOTOR CARS

BY ALEXANDER CHURCHWARD

ABSTRACT OF PAPER

A constant-speed dynamo for automobile lighting and for battery charging is to be preferred to other designs chiefly because it has the correct characteristics for its assigned work, because its efficiency is high while the wear is small, and because it is able to maintain a potential at the lamps so constant that it will even carry the lamps with the battery disconnected without injuring them.

The generator and starting motor should be built as separate electric units because of the lighter, smaller, less complicated battery required, because of the greater reliability of the separate units, and because the characteristics of the starting motor (necessarily series-wound) are directly opposite to those of the generator (which is of necessity either shunt or compound-wound).

A paper to be presented at the 288th Meeting of the American Institute of Electrical Engineers, New York, November 14, 1913.

(Subject to final revision for the Transactions.)

ADVANTAGES OF CLUTCH TYPE GENERATOR AND SEPARATE STARTING AND LIGHTING UNITS FOR MOTOR CARS

BY ALEXANDER CHURCHWARD

For supplying current for starting and lighting the modern motor car a constant-speed dynamo has many advantages over every other type of dynamo, viz:

1. It charges a battery as it should be charged; that is, with a comparatively large current when the battery is low and empty, tapering off to a small charging rate when the battery is full and at the gasing point.

2. Its comparatively low speed, even at high car speed, means long life, small wear and maintenance, and—what is most necessary—reliability.

3. Its efficiency, even with great slipping of the clutch, is higher than that of a machine controlled by a "bucking series" coil or by regulation of the field current.

In other words, the loss due to the friction and slipping of the clutch is less than the core loss of variable speed machines running at high speeds.

4. Its ability to run the lights, even when the battery is disconnected—accidently or otherwise.

5. It can be geared to cut in at very low car speeds, as the speed of the dynamo armature never exceeds a safe, predetermined limit.

Experience has shown in the past four years that it is far better to charge a battery at a moderate rate whenever the car attains a speed of 8 miles (12.8 km.) per hour than to charge at a very low rate at 10 miles (16 km.) per hour and gradually increase the charging rate as the car speed rises. A variable-speed,

constant-current dynamo, giving enough current to take care of the lights, invariably over-charges the battery on long day-light runs of some hours' duration. The user may not have to renew the battery frequently, but the direct effect is to boil the solution out of the battery, and at some time when current is

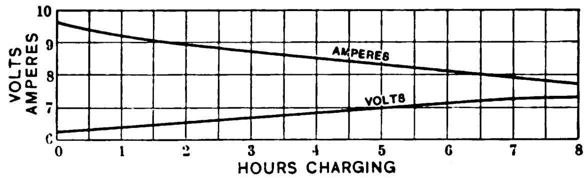

FIG. 1—TAPER CHARGE EFFECT OF CONSTANT-SPEED DYNAMO.

needed the battery fails because of a lack of electrolyte; or whatever electrolyte is left is so concentrated as to injure the plates.

This is not the case with a constant-speed machine, which gives neither constant current nor constant potential. When the

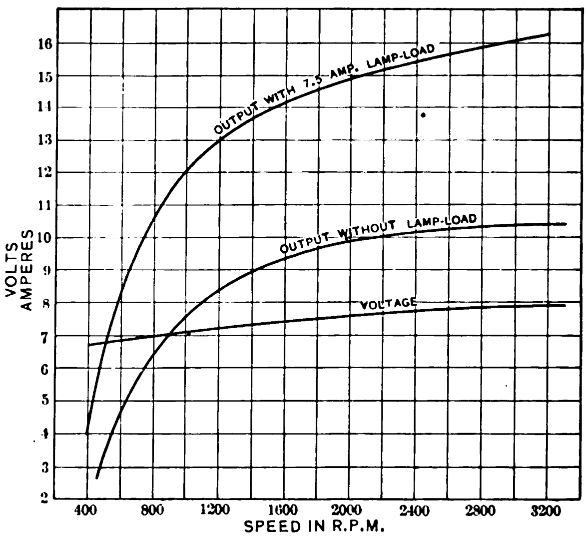

FIG. 2—OVERCHARGING EFFECT OF VARIABLE-SPEED DYNAMO.

battery is low it will give a comparatively heavy current, say 10 amperes, which will taper off to four or five amperes as the battery becomes fully charged, the voltage rising from approximately 6.5 volts to 7.75 volts when battery of three cells is fully charged. Fig. 1 shows the tapering charge effect; while Fig. 2

shows the over-charge effect of a variable-speed machine; the battery voltage rising to over eight volts, from which of course the lamps and battery would both suffer.

The constant-speed machine can be compounded so that when lamps are turned on it will maintain a constant potential of a proper value at the lamps.

The advantages of the compound wound, constant speed dynamo, that is compound wound for lighting and shunt wound

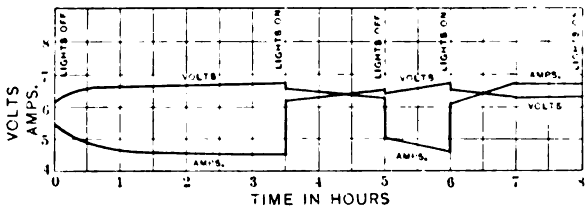

FIG. 3—TAPER CHARGE AND COMPOUND CHARACTERISTICS OF DYNAMO.

for charging battery, must be at once apparent to even the most casual observer:

1. Proper rate of charging, dependent upon condition of battery.

2. Tapering charge as battery is filled up.

3. Sufficient current to light the lamps and to put a small charge into the battery. Take for example a system equipped with lamps that call for a total of eight amperes at six volts:

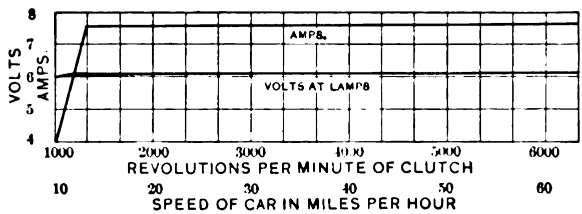

FIG. 4—VOLTAGE AT LAMPS AT DIFFERENT SPEEDS.

The charging rate to the battery will vary from 10 amperes when the battery is cold and low to five amperes when the battery is warm and charged.

If we now turn on the lamps, which are connected through the series or compound winding, the machine will give nine amperes, the battery receiving at first one ampere, while its counter electromotive force is high from just coming off charge; but it will gradually settle until the dynamo is giving 10 amperes,

eight of which go to the lights and two to the battery. This will keep the battery voltage at approximately 6.6 volts. There will be a drop in the wiring, instruments, etc. of from 0.4 to 0.5 of a volt, so that the voltage at the six-volt lamps will be main-

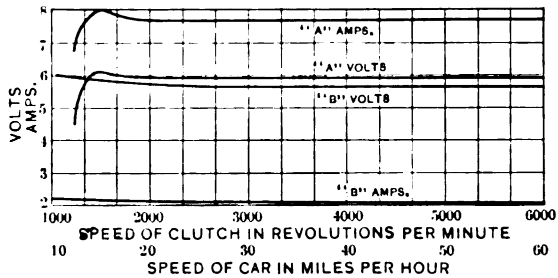

FIG. 5—VOLTAGE AT LAMPS WITH VARYING SPEEDS; BATTERY DISCONNECTED.

tained within 0.1 of a volt. Figs. 3, 4 and 5 show how the potential is maintained at the lamps.

Mention has been made above only of a lamp potential of six volts, corresponding to three cells of lead battery, as we have

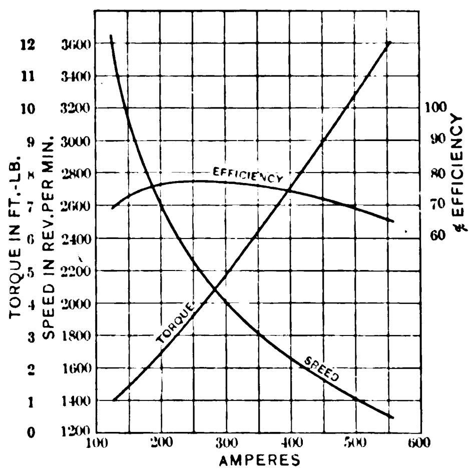

FIG. 6—CHARACTERISTICS OF SIX-VOLT SERIES-WOUND STARTING MOTORS.

found that it is possible to design our starting system so that we have a more efficient motor at six volts—the standard voltage for ignition—than most of the other systems using 18 to 24 volts.

Experience in designing electric automobile motors during the past 15 years has demonstrated that to get the most out of a battery, regardless of the number of cells, the best design which can be emloyed is a series motor with a steep torque characteristic (see Fig. 6).

A shunt-wound dynamo at constant speed being the best for charging batteries, and having characteristics exactly opposite to those of a series motor, explains the reason for our adopting the two-unit electrical system for starting and lighting. For the same generator output and the same power delivered as a motor, a single unit cannot be built any lighter or cheaper than a two-unit system.

It is unnecessary to point out why the two-unit electrical sytem is more reliable than a single-unit system, as one unit can fail without crippling the car.

In regard to weight of different voltage systems, the single unit system almost always calls for a larger number of cells in series for starting, and in multiple for lighting. The battery capacity is invariably fixed by the lighting conditions, and not by the starting conditions; and the amount of power required for starting is very small compared with that required for lighting. In fact, it is only a surface discharge. For instance: Take a six-volt battery of 80 ampere hour capacity, that is, eight amperes for 10 hours. It will require 11 plates per cell, five positive and six negative, or 15 positive and 18 negative total; and compare it with a battery for 24-volt starting system using four sets of batteries in parallel for lighting, each cell consisting of two positive plates and three negative, or a total of 24 positive and 36 negative, let alone extra jars, acid, connectors, etc., which will increase the weight approximately 20 per cent above that of the six-volt battery of the same capacity.

Take another example of a 12-volt starting, and 12-volt, three-wire lighting system: The same battery capacity will be needed, only in this case 40 ampere hours at 12 volts; therefore, there will be three extra positive and six extra negative plates, or one per cell; also extra acid, extra connectors, etc.; and the increase of weight will be approximately 10 per cent, or as much as the weight of the generator unit itself.

Therefore, the writer maintains that a six-volt double unit system properly designed and built will weigh less and be more efficient per pound than any system designed for a higher voltage.

ELECTRICAL EQUIPMENT OF GASOLINE AUTOMOBILES

BY

FRANK CONRAD

1995

ELECTRICAL EQUIPMENT OF GASOLINE AUTOMOBILES

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ABSTRACT OF PAPER

The relative merits of various ignition devices are discussed and the use is advocated of an induction coil operating from a constant-potential circuit in connection with a device which will limit the current at low speeds and still permit sufficient current flow at the higher speeds. A variable-contact device is used to operate the coil at its most efficient point and this eliminates to a considerable extent the necessity of manual control of the firing point. This ignition system produces a spark no matter how slowly the engine is turned over, thus lending itself particularly to electric motor starting.

A lighting generator should be capable of supplying current equivalent to the average lamp load, when the car is running at a speed of fifteen miles per hour. The method of regulation advocated is a demagnetizing series coil in the battery circuit, thus maintaining constant charging current. The lighting circuit is so connected that the current to the lamps will not pass through the series coil, thus tending to maintain a constant charging current independent of the lamp load.

For starting purposes two schemes are possible, namely, the use of the lighting generator as a motor, or the use of a separate motor. The separate starting motor is advocated and its characteristics are discussed.

A paper to be presented at the 288th Meeting of the American Institute of Electrical Engineers, New York, November 14, 1913.

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ELECTRICAL EQUIPMENT OF GASOLINE AUTOMOBILES

BY FRANK CONRAD

The principal electrical devices used on the gasoline automobile perform the functions of ignition, lighting and engine starting, their relative importance being in the order given. The service of the first two elements is of a continuous nature; that of the third is intermittent and momentary. The success of the gasoline motor is intimately connected with the success of the ignition system, a condition which has resulted in the development of this device to a high degree of perfection.

The ignition device in its simplest terms consists of a source of electrical supply, an induction coil for producing a high voltage discharge from an insulated to a grounded electrode in the firing chamber, and a control device or timer for making and breaking the primary circuit of the induction coil. The conditions which have to be met by this ignition system comprises an unfailing source of electrical energy, an igniting spark at all operating speeds and accurate timing of this spark. The dry batteries used in the earlier systems were found to be unreliable. This caused attention to be turned to some form of generator and due to its greater simplicity and greater range of operating speed, the permanent magnet type, or magneto, was found to be the most suitable. This apparatus possesses several inherent features which are desirable in a spark-producing device. Thus the voltage induced in its windings is approximately proportional to the speed. This tends to maintain a constant spark at all speeds, as the duration of current flow in the primary circuit will be inversely proportional to the speed of the ignition device.

With the advent of electric lighting, a generator of different

characteristics from that of the ignition machine was required. As light is required during periods when the generator is not operating, the use of a storage battery is entailed, and as the generator must operate in parallel with this battery over a wide range of speed, its terminal voltage must be nearly constant over this range. For this reason, and in view of the previous high development of the magneto, it was at first found most convenient to install a separate generator for the lighting system, the ignition thus being operated from a generator having a voltage characteristic approximately proportional to the speed and the lighting system from a generator having a voltage characteristic independent of the speed within its working limits.

As a step towards simplification, it would seem desirable to modify the electric equipment so that a single generator could be used, for furnishing power both to the ignition apparatus and the lighting system. It is of course evident that this generator would require to be of the constant voltage type, as it is necessary that it operate in conjunction with a storage battery. This involves the redesign of the ignition system so that it will operate from a constant potential supply. The earlier form of ignition device, consisting of an induction coil having a vibrating contactor and controlled by a timing device driven synchronously with the engine, met this condition, but it embodied several defects that it was possible to correct in the magneto ignition device. In a simple induction coil device, the contact is made at a predetermined point on the travel of the engine crank shaft, and after the elapsed time required for the current to build up in the primary of the induction coil, it is broken by the magnetically operated vibrator. This vibrator continues to make and break the primary circuit as long as the contact on the engine-driven timer remain closed. The result is a series of sparks in the engine cylinder at each firing period. Due to the fixed time period between the make of the circuit by the timer and the spark in the cylinder, there will be a corresponding lag of this spark as the speed of the engine is increased, thus requiring adjustment of the timer for the particular speed at which the engine is operated in order to obtain efficient results.

To obviate this, the time of break in the primary of the ignition system should be mechanically determined by the rotation of the engine, thereby avoiding the lag inherent in the magnetically operated breaker.

In the magneto device, this condition is met, as no magnetic-

ally operated contactor is used, the primary circuit being opened and closed mechanically by the rotating element. Therefore, there will be no lag of the spark as the speed of the engine is increased. This, however, implies that the duration of current flow in the primary circuit will be correspondingly shorter at the higher speeds. However, as the magneto generates a correspondingly higher voltage, the result will be an increased rate of building up of primary current which will compensate for this shorter time, thus maintaining a constant volume of spark. Unfortunately, in actual practise, this condition will be somewhat overdone, thus at the low operating speeds, the voltage generated will be insufficient to produce normal current flow, owing to the resistance and losses in the device, and, at the very high speeds, the voltage will have increased to such a value that the resistance losses will have a very slight effect, so that the secondary induced current will reach its highest value.

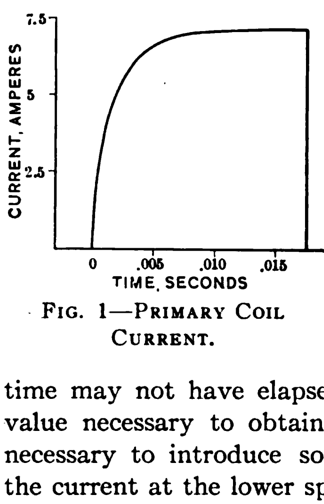

FIG. 1—PRIMARY COIL CURRENT.

In the case of the ignition device operated from a constant-potential circuit and having a fixed angular time of contact, the opposite result will be obtained; that is, at the very low operating speeds, the current in the primary circuit will build up to a value determined only by the resistance of the circuit, while at the very high engine speeds, sufficient time may not have elapsed for the current to build up to a value necessary to obtain a satisfactory spark. It is therefore necessary to introduce some opposing feature which will limit the current at the lower speeds, and still permit of sufficient flow at the higher speeds. A device in which this has been accomplished will have advantages over the magneto, in that it will have no minimum operating speed, and, in addition, at the higher operating speeds, the secondary current will not be of sufficient value to burn away the spark plug electrodes unnecessarily.

The oscillograms show the current wave shape of the primary and secondary circuits of an induction coil used with such a system. Fig. 1 is the primary current, in which contact has been made for a sufficient time to allow the current to build up to its maximum value, which is approximately eight amperes. With

this coil a primary current of about five amperes is required to give a satisfactory discharge in the secondary circuit, and from the oscillograms it can be seen that about 0.003 second is required for current to build up to this value.

In the case of the four-cylinder engine in which the ignition device is driven at engine speed, this would require an arc of contact at 200 revolutions per minute of 3.6 deg., and at 2000 revolutions per minute, 36 deg.

Fig. 2 is an oscillogram of the current in the secondary circuit of this coil. Fig. 3 shows an oscillogram of the secondary circuit of a well known magneto ignition device. A comparison of the two oscillograms would indicate that the magneto would produce a very much hotter spark than in the case of the constant potential device. Analysis, however, will show that

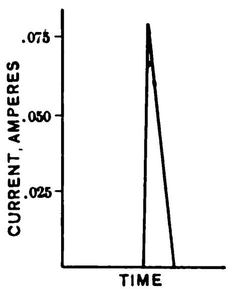

FIG. 2—SECONDARY COIL CURRENT.

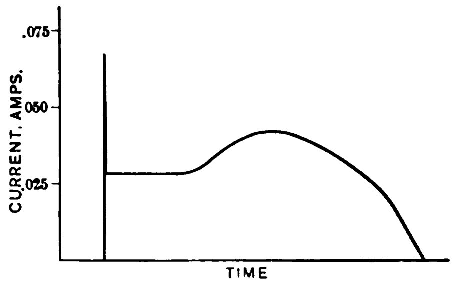

FIG. 3—MAGNETO SECONDARY—FULL ADVANCE

the initial current flow of the two devices is practically the same, the difference being that, in the case of the magneto, this flow is maintained for a considerable period, the maintenance of the current being brought about by the construction of the magneto, in that the primary and secondary windings are wound directly on the revolving armature, the secondary winding therefore cutting the magnetic field by the revolution of the armature, the same as the primary circuit. When due to the interruption of the primary circuit, an induced voltage is set up in the secondary circuit; the current flow across the spark plug electrodes, which is started by this high voltage, will be maintained by the voltage induced by the rotation of the secondary winding in the magnetic field. This continued current flow, however, has no practical advantages, as the explosive gases, which directly surround, and are in range of, the sparking points, are

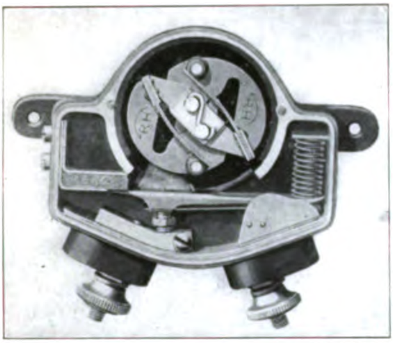

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FIG. 4.

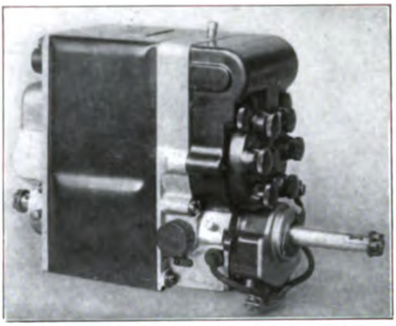

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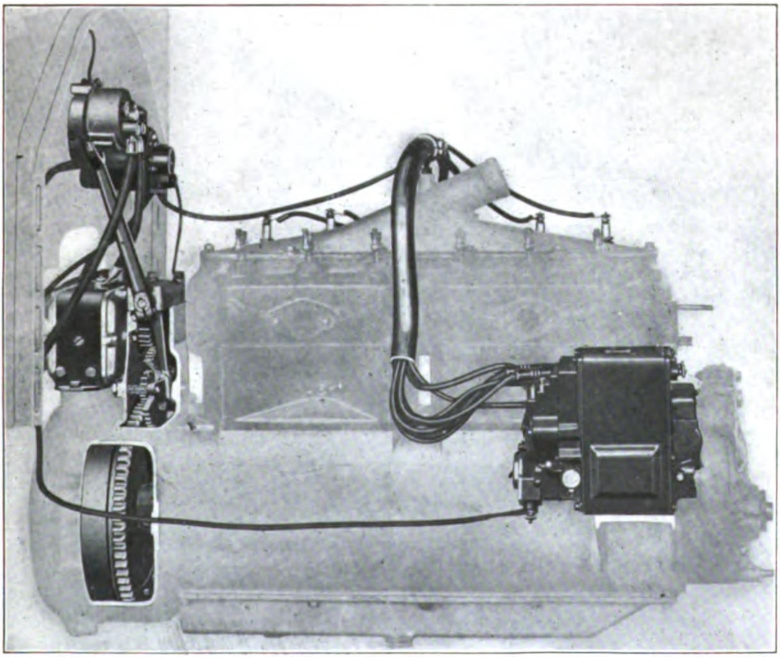
FIG. 5.



[CONRAD]

FIG. 9.

burned in a period of time probably not exceeding 0.001 second. A continued maintenance of the arc would therefore be of no further value, and would only cause the spark plug electrodes to be needlessly burned away.

An interrupter mechanism for controlling the flow of primary current, and which has been designed in line with the conditions outlined above, is shown in Fig. 4. In this device the angular time of contact is varied with the speed within working limits, so that the primary current will, at all speeds, build up to approximately the same value, thus producing a constant spark in the explosion chamber.

This action is brought about by two centrifugal operating cams which change their position with change in speed so that the contact device is held closed for an approximately constant time. This cam device not only performs the function of maintaining a constant angular time contact, but also advances the time of break with increase of speed to allow for the average time required for the combustible mixture in the cylinder to explode. This, in the magneto device, is accomplished by manual adjustment for the different speeds.

It is not possible to eliminate entirely the manual control, as there are other conditions than that of speed which determine the proper firing point, such as the quality of the explosive mixture and the temperature of the engine cylinders. This adjustment, however, is not required for each change in speed, but rather for the general conditions under which the engine is operating, so that only occasional attention to this control will be required. By the use of this variable contact device, it is possible to operate the coil at its most efficient point, thus obtaining a good spark throughout the working range of speed and with a minimum current consumption.

An advantage of an ignition system of this type is that it is possible to mount it directly on the lighting generator so that it forms part of the same, thus obviating the additional drive which is required in the case of a separate ignition system and, furthermore, it has the advantage over the magneto type, in that it has no minimum operating speed, a spark being produced no matter how slowly the engine is being turned over, thus lending itself particularly to applications in which an electric motor is used to turn over the engine for starting purposes.

As it is desirable that the combined generator and ignition device be installed on the same mounting and drive furnished

for the usual magneto, the generator should be so designed that it will have the proper range of operating speed. For a four-cylinder arrangement this is equivalent to the engine speed, and, on a six-cylinder engine, to one and a half times engine speed. It has been found in practise that it is desirable to have the generator capable of delivering an amount of current equivalent to the average lamp load when the car is being operated at a speed of 15 miles (24. km.) per hour. With the average gear ratio and size of wheels, this would be approximately 500 rev. per min. of the generator, the maximum running speed would be in the neighborhood of 2000 rev. per min. This would give a working range of speed of from 500 to 2000 rev. per min. on the four-cylinder, and 750 to 3000 on the six-cylinder engine.

The illustration, Fig. 5, shows a completed device of this type suitable for a 6-cylinder engine. The induction coil is mounted directly in the high-tension distributor, so that there are no high-tension connections except the leads to the spark plugs on the cylinders. It, therefore, in all respects, will be equivalent to a high-tension magneto of the self-contained type, and has advantages of a constant spark at all speeds, thus giving very good operation at low engine speed, and of furnishing power for lights and charging storage batteries. The regulation of the generator is obtained by means of a demagnetizing series coil in the circuit of the battery, thus maintaining constant charging current. The lighting circuit is so connected that the current supplied directly to the lamps will not pass through the series coil. This tends to maintain a constant charging current independent of the lamp load, and allows of this charging current being adjusted for a minimum value. The curve, Fig. 6, shows the output of this generator at varying speeds, with and without a lamp load of nine amperes.

For starting the gasoline engine, a motor is used which draws power from the storage battery. There are two general schemes possible, namely, the use of the lighting generator as a motor, and the use of a separate motor. The power required for turning over the average engine, at the speeds commonly employed, will range from one-half to one horse power. It is therefore evident that, if the lighting generator should be used as a starting motor, and at its normal operating speed, it would require an extremely heavy machine. In order to reduce this weight, a special driving arrangement might be furnished which would allow the generator to operate at engine speed when

being driven as a generator, and allow a considerable speed reduction from this generator to the engine when being operated as a motor. This implies a low-speed generator and a high-speed motor, which, for efficient design, necessitates double windings and commutators. Due to the general complication of this arrangement, the scheme of using a separate starting motor is to be preferred. This motor can have its proportions best worked out for its operation as a motor, and without the use of any inactive material, which would be necessary in the case of a combination machine. In order to reduce its weight to the lowest possible amount, it should be

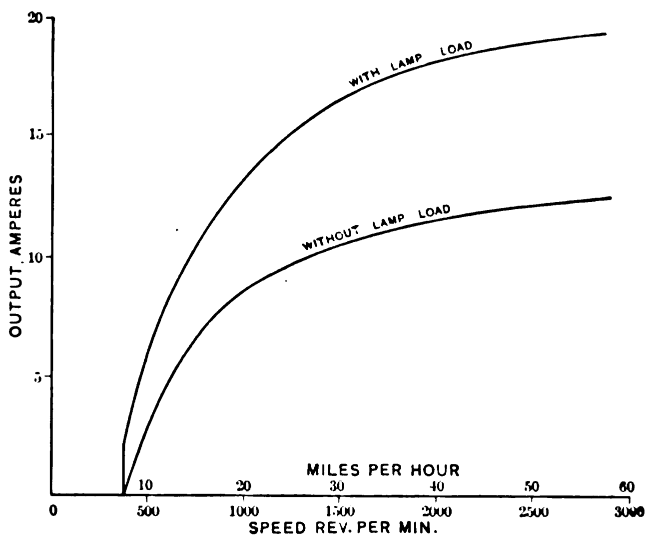


FIG. 6.

operated at the highest speed consistent with the use of an efficient gearing between the motor and engine, the normal operating speed, in actual practise, being between the limits of 1000 and 2500 rev. per min., the higher speeds being used where weight is the paramount consideration, and the lower speeds being used where it is necessary that a very quiet drive be obtained.

From the point of view of the design of the motor, there are no particular characteristics required other than those obtained with a series motor. The efficiency should be as high as is consistent with light weight, and the locked torque should be as

great as possible, in order to minimize the possibility of failure to start when the engine is cold and stiff.

In the gearing between the motor and engine, there are certain conditions which must be met, due to the peculiarity of the load which the motor is driving. It is necessary to intro-

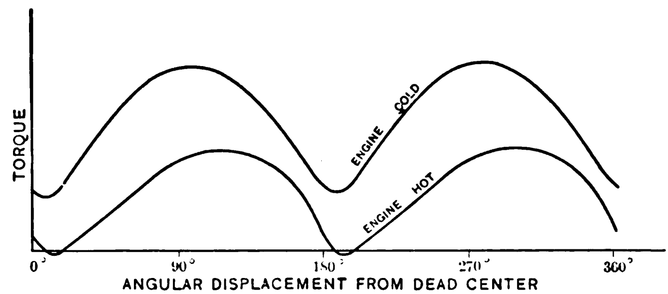


FIG. 7—TURNOVER TORQUE OF FOUR-CYLINDER ENGINE.

duce some device which will prevent the gasoline engine from driving the motor, as, due to the comparatively high gear ratio, the motor will be operating at an excessive speed at even a comparatively low operating speed of the gasoline engine. This device consists of what is known as an over-running clutch. The torque also varies considerably during each revolution of

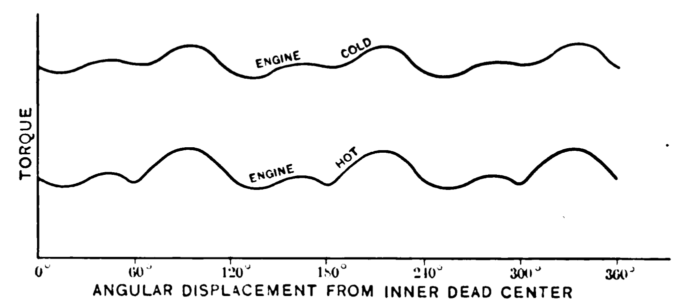


FIG. 8—TURNOVER TORQUE OF SIX-CYLINDER ENGINE.

the engine, due to the compression and expansion of the gases in the cylinders, this variation, of course, being much greater in a four- than in a six-cylinder engine. The curve, Fig. 7, shows the relative torques required by a four-cylinder engine under two conditions, namely, that of low temperature involving high friction losses due to cold oil in the bearings, and under the

condition of high temperature, which greatly reduces the friction. The curve, Fig. 8, shows the torque required by a six-cylinder engine under the same conditions.

It will be seen that in the case of the hot four-cylinder engine, the torque required to drive it during certain parts of a revolution is negative, the engine thus tending to drive the starting motor. In order to secure a quiet drive, it is essential that, in the disconnecting devices used between motor and engine, there be no appreciable back-lash or lost motion in the over-running clutch device. The effect of this, however, can be minimized by reducing the inertia of the starting motor armature so that it can more closely follow the speed of the gasoline engine over the period of negative torque. The effect also decreases with increase of cranking speed.

As the service of the starting devices is of a momentary nature, it is customary to so proportion the design that the apparatus is worked under conditions of excessive overload, as compared to continuously operated devices. This is particularly true as regards the storage battery, the usual discharge rates being somewhere in the neighborhood of the 20-minute rate. In order to reduce to a minimum the internal drop under this excessive rate, a much thinner plate is used than is the case with batteries intended to be operated only under normal rating. The continuous capacity of the motor should be such that it can completely discharge a fully charged battery under any conditions without injury.

Fig. 9 shows a complete installation on an automobile engine of a set of units as described above. In this application, the starting motor is mounted on the top of the flywheel casing and drives the engine through a gear cut in the periphery of this flywheel, a push button projecting through the dash serving to operate the control switch and shift a sliding pinion into mesh with the flywheel gear.

Where the starting motor is connected to the engine through the medium of a chain drive there is no sliding gear used, but the sprocket wheel on the engine shaft drives through the medium of an over-running clutch. This allows the starting motor to drive the engine, but permits of free running of the engine, independent of the starting motor. The control device consists of a simple switch in the starting motor circuit.

MIDWINTER CONVENTION PAPERS

GROUP II. METHODS OF DETERMINING LOSSES IN APPARATUS.

(a) INDUCTION MOTORS

Induction Motor Load Losses, by H. G. Reist and A. E. Averrett.
Stray Losses in Induction Motors, by A. M. Dudley.
Notes on Induction Motor Losses, by R. W. Davis.

(b) TRANSFORMERS

Losses in Transformers, by W. W. Lewis.
Stray Losses in Transformers, by C. Fortescue and W. M. McConahey.

(c) GENERATORS, A-C. AND D-C.

Determination of Load Loss Correction Factors for Rotating Electric Machines, by E. M. Olin and S. L. Henderson.
Load Losses of Alternating-Current Generators, by W. J. Foster and E. Knowlton.
Notes on Stray Losses in Synchronous Machines, by F. K. Brainard.
Stray Loss in Direct-Current Commutating Machines, by H. F. T. Erben and H. S. Page.

(d) ERRORS OF TESTS

The Determination of Stray Losses from Input-Output Tests, by L. T. Robinson.
Sources of Error in the Efficiency Determination of Rotating Electric Machines, by Elmer I. Chute and William Bradshaw.

(e) BRUSH LOSSES

Brush Friction and Contact Losses, by H. F. T. Erben and A. H. Freeman.
Methods of Determining Brush Losses Due to Contact and Friction, by H. R. Edgecomb and W. A. Dick.
Commutation and Brush Losses, by C. E. Wilson.

Discussion on Group II Papers (Methods of Determining Losses in Apparatus), New York, February 27, 1913. (See Proceedings for February, 1913.)

(Subject to final revision for the Transactions)

(a) Induction Motors

A. E. Averrett: Regarding the separation of copper losses, there seems to be a tendency on the part of some users to want bar-wound stators on account of the ease of repair. You can make a bar-wound stator with rather deep bars, but if you have a rotor that is bar-wound also and assume that the losses are practically all in the rotor, these will disappear at synchronous speed and you will apparently have a more efficient machine than you really have, if all the losses are taken into consideration. But you can actually get the loss by taking out the rotor and measuring the impedance of the stator alone by wattmeters, which will show up the losses correctly if the tests are made carefully.

It seems to me that the present method of summation of losses will apply only where the impedance-ampere curve is a straight line proportional to voltage (which shows no saturation in the iron) and where there are no eddy losses in the stator copper, which can be shown up by the wattmeter measurement at impedance. There is one feature about a deep rotor bar where we neglect the losses; there is a reduction in power factor due to skin effect in deep rotor bars which does not show at standstill test.

B. A. Behrend: I want to make a plea for the adoption of the term "stray losses" instead of the term "load losses" or losses incidental to operation. We understand by "load losses," as the term is used, a great many losses, including certain losses which occur at no-load, losses which occur in certain cases at full load, and losses which occur at both no-load and full load, and I think the adoption of the term "stray losses" would be a little more logical. We have a certain stray loss at no-load, we have a certain stray loss at full load, and instead of the use of the term "load loss," which is used in some of these papers as a loss occurring at no-load, I think we should use the term "stray loss." I believe that Mr. Hobart, who suggested my making these remarks, agrees with the substitution.

C. P. Steinmetz: We are particularly interested in the magnitude of the additional stray losses which we have at load, and we are only in a less measure interested in the stray losses at no-load. These latter need rarely be segregated from the total losses at no-load. We need a satisfactory name for those losses which appear at load, and are not accounted for by the usual methods of measuring individual losses. "Load loss" is rather a poor name, because there are many other losses which are accounted for in a separate test; but "stray loss" does not cover it exactly either, and we should have some additional name.

James Burke: Following Dr. Steinmetz's remarks, would it be consistent to speak of "stray no-load losses" and "stray load losses?" We have both kinds of stray losses. These papers show that in some kinds of motors the stray load losses may be very considerable. In other types they may be very small. Generally, the reduction in core losses due to the drop in the stator windings, resulting in lower total magnetization, compensates for the usual load stray losses, so that there is not very much to be taken into consideration if the free core losses are used rather than the corrected core losses after the reduction in the magnetism in the machine. It would seem, however, that in formulating any new rules, we must take proper recognition of the stray load losses, because from these papers it is evident that we may have very considerable stray load losses, or they may be negligible, and that fact would seem to make it necessary to formulate some plan by which they would be properly taken into consideration when they exist.

H. M. Hobart: We ought to have four components in this proposition. The four components I have in mind are: First, output; second, no-load loss; third, the load loss (by which we mean the legitimate load loss), increasing as the square of the current; and fourth, what we might call "stray losses," that is, the losses which, at full load, we must add to these other three losses in order to get the input at full load. This fourth part, which we have been apt to ignore in the past, and which we shall probably have to take into account in the future, could be given the name "stray losses," instead of, as in some of the papers, being termed "load losses." I should prefer to reserve the term "load losses" for what we call the legitimate losses coming on with the load.

Leo Schuler: Does Mr. Hobart propose to call losses due to distortion of the field stray losses as well? They certainly are not stray losses.

H. M. Hobart: For practical purposes I should have input, minus output, minus no-load losses, minus I^2R losses, coming on with the load, which I should call stray losses.

Leo Schuler: You then include losses which are not stray losses.

Perhaps it will interest you if I say that in Germany we have the no-load losses, which include also stray losses if there are any, and then speak of "additional losses" simply. Additional loss means the loss which does not come on at full load, and which is not accounted for by what you call the load losses.

B. G. Lamme: Stray losses?

Leo Schuler: As far as I understand, load loss is better than stray loss.

H. M. Hobart: I do not care what it is called, if we do not confuse it with other losses. "Extra losses" would be a good term.

B. A. Behrend: The objection is to the use of the term "load loss." It is not implied that the expression "stray" is such

a general term, but it might be as good a one as any other. An objection to using the term " load losses " is that in an equivalent test it might mean legitimate losses or extra losses.

B. G. Lamme: The term " load loss," as Mr. Behrend says, is a very misleading one, because practically all our secondary copper loss is a load loss. Practically all of our primary copper losses are load losses, and when we speak of load losses we should include all these, and yet what we are after is the additional extra loss which we call the " stray loss." I do not think, whatever other term we use, that we can dispense with the use of that term—after we have described our " load losses," we will still have use for that term " stray losses," or some other similar term.

A. E. Averrett: I believe load losses are included in the legitimate copper losses and legitimate iron losses, plus excess losses. On induction motors, these losses occur only on the load running light. There is no excess loss.

R. E. Hellmund: The present Institute rules are not quite right, in so far as they give the losses in too general a way. These papers give suggestions as to the method of determining the losses for practically all cases, with the possible exception of machines with entirely closed slots. As has been said, such cases are comparatively rare. All other cases can be taken care of, if the Committee would adopt the suggestions made in the paper of Messrs. Reist and Averrett, and the paper of Mr. Dudley.

It might appear at first sight that Mr. Dudley's suggestion of finding the true I^2R loss by testing the motors for different frequencies is impracticable, but it must be considered that almost any factory has generators available with at least two or three frequencies. Since the method is on the other hand the only method proposed for finding the I^2R losses in large squirrel-cage motors, I would advocate that the Institute adopt this method as one of its standard methods.

C. J. Fechheimer: Messrs. Reist and Averrett make the following statement: " Tests have been made which verify the above statements; round wire or rectangular strip of one cm. or less for a maximum dimension, apparently do not show any appreciable loss." This refers to eddy current losses in copper conductors. I would call attention to the fact that eddy currents are a function of the frequency and increase very rapidly with an increase in frequency. At standard frequencies the loss is negligible with the depth of conductor given, but it would be possible to raise the frequency high enough to cause a very large eddy loss with the same size conductor.

We believe that the method which is mentioned briefly at the end of this same paper, that is, of obtaining the losses at various frequencies, would be the proper one to determine the extent of the eddy losses. If we go down low enough with the impressed frequency the eddy current loss becomes negligible

and we then have a direct means of measuring these losses with accuracy.

R. E. Hellmund: We first have to find out what the extra losses are at standstill and then separate them. Mr. Dudley proposes to find out what they are by measuring at different frequencies and then separating them, either by the rule of making them proportional to the square of the depth of the conductor, or by taking the rotor out of the stator and testing the stator separately.

There are two steps to be taken, and I think they are very proper steps, in large machines, where it is not possible to get the secondary losses by slip readings. In smaller machines I think the method proposed by the first paper is very desirable that is, to get the secondary losses by slip readings and the primary losses by considering the I^2R losses, or, in the case of heavy conductors, by making the additional test of the stator without the rotor.

Comfort A. Adams: I want to say a word in favor of the German name translated as "additional losses". The term "stray losses" has been for many years much used to represent the no-load losses, that is, the friction and windage losses, and losses measured when the machine is running absolutely light. Thus in order to avoid confusion it seems to me that "additional losses," a perfectly distinct name, would be more appropriate. Referring to Mr. Fechheimer's question as to iron slot bridges and the reduction of the total flux at full load, it is obvious that if you mean by total flux the useful working flux, plus the leakage flux, it is practically constant at constant impressed voltage, differing therefrom by only the IR drop, which is small. But the part of this total flux which is increased by the bridges, namely, the leakage flux, is in a magnetic circuit of relatively short length, and involves a much smaller volume of iron, although at much higher density. It is thus impossible to say, definitely, whether the bridges would increase or decrease the total core losses.

James Burke: I want to answer Professor Adams' point regarding the difference in core losses. Very often on motors below 10 h.p. there is a 5 per cent reduction of e.m.f. due to 5 per cent drop, which makes about 5 per cent difference in core loss. On larger motors this is much less, but in motors of 10 h.p. or less a large IR drop in the stator generally exists.

Comfort A. Adams: Mr. Burke's statement is undoubtedly correct, but if the resistance drop is constant for any given load, say full load, the effect of the slot bridges is not to change the total flux, but to increase the leakage flux at the expense of the main flux as above described.

B. A. Behrend: It seems to me extremely dangerous to draw an inference from the excess over an assumed rate of increase. We are familiar with the fact that the core loss in induction motors rises at a greater rate than the square of the

impressed voltage, and, therefore, any inference based on the law of increase as suggested would be, to borrow a phrase used by Mr. Burke, "mind reading" rather than good engineering.

A method of that sort seems most dangerous to me, and in this connection I wish to second the remarks made by Mr. Schüler and Professor Adams on the use of the term "indeterminate losses." It seems from the discussion that the use of the term "indeterminate" would be excellent, because no one knows how to determine them.

C. P. Steinmetz: In connection with Mr. Behrend's remarks, I wish to say that I have never seen any core losses go up faster than the square of the voltage, or even as fast as the square of the voltage, except in those cases where there was saturation somewhere. Practically any core loss, if you run the voltage high enough, will begin to rise abruptly at the point where saturation is reached, and then the increase goes up according to powers ranging from the square to the cube and sometimes even at still greater rates. The abrupt increase of core losses beyond the quadratic rate at high voltages is an indication that saturation is the cause.

In view of the general experience with core losses in commutating machines, and in motors, especially in the commutating induction motor, we must expect that as soon as saturation is passed anywhere, we will have an abnormal rise of core loss, but below saturation the core loss does not go up as the square.

B. A. Behrend: I do not question the approximate truth of the 1.6th power law of Mr. Steinmetz's—but this is not a practical condition, obtaining in any generators or motors and therefore the core loss does increase more rapidly than the 1.6th power or even the square, at high inductions.

C. J. Fechheimer: I plotted a number of core loss curves on generators far below the saturation point, plotted them on logarithmic paper to determine the exponent, and I found in a number of cases the exponent was higher than 2. There were a couple of cases below 2, but the general average was around 2, below saturation, and I have never been able to account for it.

Comfort A. Adams: The reason why the core losses behave so erratically in the case of induction motors is that they are not losses which occur, as in transformers, under conditions of fairly uniform density and single frequency. There are at least five different kinds of core losses in an induction motor, or five ways in which they occur, so that if the calculations could be made it would require five separate calculations. There are losses at fundamental frequency behind the teeth, at fundamental frequency in the teeth, at tooth frequency in the teeth, at tooth frequency in certain portions of the core back of the teeth, due to the tooth and slot groupings on the two sides of the gap, wave losses in the faces of the teeth, and, finally, illegitimate losses due to the breakdown

of the insulation between laminations. It is thus not a simple matter to compute these losses, and not strange that they do not behave according to the manner of the core losses of well-behaved transformers. The increase more rapid than the square of the voltage is due partly to the wave losses in tooth faces and partly to a progressive breakdown of lamination insulation as the eddy e.m.fs. increase.

B. G. Lamme: In some cases the so-called iron losses increase very rapidly with the load, and also very rapidly with the induction. I have found many cases in which an abnormal increase in apparent iron loss occurs with only slightly increased inductions. But in many of these cases, if the copper was removed from the slots, the loss did not go up nearly so fast; that is, the so-called iron loss was, in reality, largely eddy current loss. The confusion comes from the fact that where iron losses are referred to, in most cases the term "core loss" should really be used. Part of the extra losses found may be true iron losses, but are eddy currents in the iron due to burred edges of the laminations in the slot, due to filing, etc., but also may be due to contact between the plates. Such losses, if located in the armature teeth, may go up much more rapidly than the square of the induction, for they may be a function of the tooth saturation. I have found cases where the loss went up to as high as the 5th power of the induction, but this was largely eddy current loss in the teeth and armature copper, which is dependent upon the degree of saturation of the armature teeth. In fact, therefore, before arriving at any conclusions regarding the variation of the iron losses with the voltage, we should first find what really is iron loss and what is something else.

R. B. Williamson: Mr. Lamme has mentioned the paper by Mr. Field on eddy currents, in which the eddy current losses in conductors were shown to be due to the cross flux in the slot. In slots that have been filed or drifted, the laminations become more or less connected together, and the cross flux may set up considerable loss in the side walls of the teeth. A machine that shows high core loss on open circuit will, in many cases, also show a high short-circuit loss; that is, there is a connection between the two, and I believe a great deal of this loss is due to eddy currents in the teeth, or in the side-walls of the teeth.

B. A. Behrend: As to the discrepancies in the opinions expressed by Dr. Steinmetz and myself, let me say that core losses are not iron losses, as I have used the term, and as I believe most of us are using it. Core losses also contain indeterminate losses. The iron loss is one thing, the copper loss is another, and the core loss may contain copper losses and iron losses and losses due to the filing of cores and bad workmanship, as well as losses due to stray fields from magnetic fields in the end plates or anywhere in the machines. I think that as we measure core losses, and not iron losses, it is not rational to talk of iron losses,

except in calculations. This seems to me, from twenty years of experience, a matter of course, but I felt constrained to point it out, as the iron losses, if they could be separated and isolated, would not increase at a rate greater than the square of the induction. The core losses, however, do show such increase.

C. P. Steinmetz: I would say that transformers and induction motors for 60-cycle circuits, are two classes of apparatus in which good practise keeps the magnetic densities below saturation, or certainly does not let them go beyond saturation. Consequently, changes in voltage are not associated with changes in the flux path. As long as there is no change of flux path, all the losses must be dependent on the voltage or the current. The eddy losses would change with the square, the iron losses probably less than the square, so that the combined effect cannot exceed the square of the voltage, except where, by saturation, the flux path is affected.

B. A. Behrend: I believe there are about three million h.p. of induction motors in operation, with the design of which I have been concerned in one form or another, and I believe almost all of these induction motors carried the saturation above the bend of the saturation curve in the teeth of the rotor, and also in parts of the stator, and I am a little at a loss to understand the remarks of Dr. Steinmetz in this connection, because saturation is almost invariably used in the teeth of the rotors of induction motors, and not infrequently in other parts of the magnetic circuit.

C. P. Steinmetz: I think the confusion exists in the indefinite meaning of the term saturation. I mean such densities of saturation that the m.m.f. consumed in the iron is of the same order of magnitude per unit of length of the magnetic circuit as the m.m.f. consumed in the air-gap. That, naturally, would not be desirable. Exceeding the bend of the saturation curve is really not yet saturation, in the meaning of the term as I have used it. You can go beyond that for a little way and still not seriously increase the proportionality between the exciting current and the voltage.

H. M. Hobart: Another circumstance, as showing our ignorance of this subject, could be mentioned. If in the laboratory you measure the specific resistances of two samples of iron, one of high and the other of low specific resistance, the eddy current loss may be as great in the one with high specific resistance as in the one with low specific resistance. Pending an explanation of this, we must admit that we do not know much about eddy current losses.

L. T. Robinson: We do not know very much about these things. An encouraging sign is that we begin to take an interest in them, with the object and hope of finding out more about them.

R. E. Hellmund: It has been brought out that the core losses, as a rule, rise with the square of the voltage impressed

on induction motors, more so than in the case of transformers. That is partly due to high densities in certain parts, but I take it that most of it is due to the fact that the largest part of the losses in induction motors, of practical design, are eddy current losses, and only the smallest proportion of the losses are hysteresis losses. In considering transformer iron, with about 60 cycles, the hysteresis loss is pretty large as compared to the eddy loss. In the case of the induction motors the hysteresis losses are in many motors only about 20 per cent, while all the rest of the losses are eddy current losses, caused by the higher frequencies in the teeth. Now, as we all know, the eddy losses go up with the square of the voltage, and since the eddy losses in most motors are more than half of the total losses, it is not surprising that the curve follows the law of the eddy loss rather than that of the hysteresis losses. It is therefore really not surprising that the core loss curve is nearly the curve of the squares, even for low densities.

B. A. Behrend: Once more to the subject of saturation, and the iron losses, where hysteresis alone may be considered. Dr. Ewing, who first brought out the general principles of induction in iron and other metals, suggested to Professor Baily of London certain physical research work, the results of which are published in the *Transactions* of the Royal Society. The paper of Professor Baily is fundamental, and he proves that rotative hysteresis diminishes at high induction. With the induction plotted as an ordinate and the loss plotted as an abscissa, Professor Baily's researches show that at saturation, viz., $4 \pi I$ in the relation $\mathbf{B} = \mathbf{H} + 4 \pi I$ having become a constant, the loss diminishes. Whatever induction we have below or beyond that point is the induction, **B** which is the sum of the air field plus the iron field. This was experimentally demonstrated in Professor Baily's paper. I also carried on some experiments in our own laboratories about eight or ten years ago, and I found an approximation to a similar result. We eliminated eddy currents as nearly as possible, and we found that the loss diminished at high inductions.

M. G. Lloyd: Mr. Behrend is quite right in his reference to the experiment of Professor Baily, and further work along the same line has been done by others, especially by Professor Weiss, of Zürich. The curve between watt loss and magnetic flux density has been found to come down to almost zero at sufficiently high values of the flux-density, but this applies only to a case where you have a purely rotary magnetic field, constant in intensity and simply changing its direction in the magnetic material. I do not believe that such a condition can be found in any kind of a machine such as an induction motor. You always have there a combination of a rotary effect with a reversing effect, that is, you have pulsation of the magnetic field in both time and space. In a case like that the law illustrated by Mr. Behrend's curve no longer holds.

H. M. Hobart: In view of our demonstrated ignorance in these matters of hysteresis and eddy current losses, we must base our reasoning on the results of tests, and we should refrain from basing any conclusions on deductions from old-fashioned conventional alleged truths which have been shown to be not only inadequate but utterly misleading.

R. E. Hellmund: In considering the field distribution in induction motors, we must not only consider the effect of the primary, but also the effect of the secondary. The secondary, if short-circuited, has a correcting effect upon the field. This is especially the case in squirrel cage motors. For instance, a squirrel cage rotor with an infinite number of bars will always correct the field so it will have a sinusoidal distribution, no matter what the initial distribution of the field as set up by the primary winding. In actual practise, the correcting effect of the secondary with a limited number of slots, will be such as to cause the field distribution to be very nearly sinusoidal. We must therefore say that the chording of the primary has little influence upon the actual field distribution, but that it will have a big influence upon the correcting currents in the secondary.

In other words, we may say that the correcting secondary currents and the losses caused thereby are the smaller the more the initial field set up by the primary approaches a sinusoidal field.

The initial primary field in three-phase motors with full pitch is not quite ideal in this respect. By introducing a chording sufficient to have two of the phases overlap half-way, we obtain an almost sinusoidal primary field distribution. By chording the coils considerably more than that, the field becomes worse again and will be the same as in the case of full pitch, if two of the phases overlap entirely. In two-phase motors, the initial primary field with full pitch windings is considerably worse than in three-phase motors, but also in this case phases overlapped about one-half improve the initial primary field considerably.

It follows from the above that while the chording of the winding has no great influence upon the actual field distribution, it is, if properly chosen, an advantage with regard to the operation of the motor.

James Burke: That also happens in the loaded conditions?

R. E. Hellmund: It is pretty hard to say just exactly what happens in the loaded condition, but my previous statements certainly do apply to the synchronous condition.

Comfort A. Adams: Mr. Hellmund's statements are quite in line with my ideas in this matter, but he undoubtedly assumed one condition, which he did not mention; that is, that the correcting effect of the secondary is only complete under the assumption of zero resistance and reactance in the secondary.

R. E. Hellmund: Yes, this assumption has to be made in order to get ideal correcting effect.

Comfort A. Adams: In most squirrel cage motors this condition is, of course, nearly fulfilled. If you had zero resistance and reactance, evenly distributed, it would wipe out all kinds, no matter what the e.m.f. condition was. As you reduce the coil pitch below two-thirds in a three-phase motor, say to 50 per cent, you might assume that there would result the same perfect m.m.f. distribution as for $\frac{2}{3}$ pitch, but this is not so, because the currents in the overlapping phases have larger phase differences and yield quite different amplitudes in adjacent belts. The phase differences of the resultant currents in the various belts and the number of belts (12) is the same as for $\frac{2}{3}$ pitch, but when you go down to 50 per cent pitch, you may have what Mr. Lamme has indicated, an actual local reversal of the flux.

(*b*) Transformers

J. M. Weed: The two papers on transformer losses are in a sense complementary to each other, but after both papers are read, there are some discrepancies apparent which need to be harmonized, and some points which still need to be brought out to clear up the subject.

The paper by Messrs. Fortescue and McConahey mentions the losses due to eddy currents in the copper, and those due to circulating or unbalanced currents in unsymmetrical parallel windings, but dismisses them with the statement that they are negligible in careful designs. In the remaining part of the paper these losses are ignored, the total copper loss being classified as I^2R loss and stray loss (see section V of the paper). The term stray loss is confined to that part of the loss in the primary winding due to the resultant of load current and exciting current which is in excess of that which would be caused by the load current alone plus that which is caused by exciting current alone. In equation (**24**) the term " short-circut loss " is used as an alternative term for I^2R loss, and is intended to refer to the loss which would be caused by load current alone.

On the other hand, Mr. Lewis calls the loss due to the resultant of load and exciting currents the I^2R loss, and classifies the extra losses due to magnetic leakage, which include the losses due to eddy currents, as stray loss. Moreover, the extensive tabulations of tests given by Mr. Lewis show that these losses are often far from negligible, varying as they do from a small value to more than 50 per cent of the I^2R loss.

This discrepancy in the use of terms is no doubt the result of efforts on the parts of the authors of both papers to use in a rational and discriminating way the old stereotyped terms " load losses " and " stray losses," which have been used rather indiscriminately to cover a multitude of sins. This effort has taken different directions in the two cases.

Messrs. Fortescue and McConahey have confined the term " stray loss " to a rational significance, that of a loss which escapes measurement. This applies to the extra loss due

to combining the load and exciting currents, but not to the losses due to magnetic leakage.

On the other hand, Mr. Lewis has made the term " load loss " to include the I^2R loss, which, in so far as it is due to load current, certainly is a load loss. But he has made the I^2R loss of the primary to include the total loss due to the resultant of exciting current and load current. This loss all might properly be called I^2R loss, but not all load loss, since that element of it due to exciting current alone is included in the open-circuit or " no-load loss."

Probably the losses which Mr. Lewis has designated as stray loss would be more properly designated as losses due to magnetic leakage, or extra losses due to loading, these losses being included with the I^2R losses due to loading, under the general term of load losses, as Mr. Lewis has suggested.

I would make a similar suggestion with respect to rotating machines also, where the same difficulties have appeared in the rational classification of losses. The resistance loss in the armature winding does not seem to be logically excluded from the term load loss. Moreover, the losses due to magnetic leakage, which are properly included under the general term of load losses, may not properly be designated as stray losses, since they are included with the armature resistance loss, windage and friction, in the short-circuit core loss. The results of tests given in the papers by Messrs. Foster and Knowlton, and by Mr. Brainard, seem to indicate that these losses, as measured by this method, are not "greatly exaggerated," as stated in section 115 of the present rules, but that they are approximately the correct losses for the normal load condition.

Returning now to losses in transformers, an independent discussion of the various elements of loss and their classification may be useful. I will begin this by summarizing these elements, thus: The total losses of the transformer may be divided into those due to excitation, called no-load losses by Mr. Lewis, and those due to load, which he calls load losses. The former, ordinarily referred to as open-circuit or core loss, includes, besides hysteresis and eddy current losses in the core, a small element of resistance loss in the primary winding due to magnetizing current and a dielectric loss in the insulation which is very small in low-voltage transformers, but may be quite large in very high voltage transformers. These losses should be measured with open secondary, at rated frequency and rated sine wave voltage plus IR (instead of rated voltage minus IR). This correction of sign will be approved at once when it is considered that the rating of the transformer is based upon its output, and that the current rating is universally calculated from the nameplate voltage. The nameplate secondary voltage must, therefore, be taken as the full load voltage, while the primary applied voltage is supposed to be in excess of the nameplate primary voltage by an amount equal to the transformer drop. The excitation of the

core corresponding to full load at 100 per cent power factor, is, therefore, the nameplate voltage plus the percentage of I^2R drop in the secondary winding.

The load losses include the losses due to magnetic leakage plus the I^2R loss due to load current and the measured resistance plus the extra loss due to the combination of load current and exciting current in the primary winding. This does not include the loss due to exciting current alone, which was measured with the open-circuit loss. The losses due to magnetic leakage and the I^2R loss due to load current are included in the measured short-circuit or impedance loss, but not the extra or stray loss due to exciting current. This loss is usually very small, but may be included by a correction, based not on the total short-circuit loss, as stated in equation (**24**) by Messrs. Fortescue and McConahey, but on the I^2R loss due to load current. Moreover, the total exciting current does not enter into this correction, but only the fundamental component of the exciting current. The correction may then be made exact, including the effect of the hysteresis angle, by the formula:

Total loss in copper — loss due to magnetizing current alone = extra loss due to magnetic leakage + resistance loss due to load current $\times$ $[1 + 2\,pq\ (\cos\theta\ \cos\theta' + \sin\theta\sin\theta')]$*
where

$$p = \frac{n_1\,(I_e)_1}{n_2\,I_2}$$

and

$$q = \frac{\left(\dfrac{n_2}{n_1}\,I_2\right)^2 R_1}{\text{total resistance loss due to load current}}$$

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*The derivation of the formula given above for correcting I^2R loss to include stray loss due to exciting current is obtained as follows:

Referring to Fig. 2 page 2022, the fundamental component of exciting current,

$$/I_e/_1$$

may be separated in two components a and b, the former in phase with the load current, the latter at right angles to it. Represent the load current in the primary winding

$$\frac{n_2}{n_1}I_2 \text{ by } c.$$

The total loss due to these currents is

$$[a^2 + (b + c)^2]\,R_1 =$$
$$(a^2 + b^2 + c^2 + 2bc)\ R_1$$

The loss due to the fundamental component of exciting current alone is $(a^2 + b^2)\,R_1$. The loss due to the harmonics of exciting current must be added to this, but these components do not affect the extra loss due

and where

$$\cos \theta = \text{power factor of the load}$$

and

$$\cos \theta' = \text{power factor of } (I_e)_1$$

$$(I_e)_1 = \text{fundamental component of exciting current}$$

With 10 per cent exciting current, which is the maximum value that should occur in practise, the fundamental component would probably be about 8 per cent so that $p = 0.08$. Assuming a core loss of one per cent, we have $\cos \theta' = 0.125$, and sine $\theta' = 0.993$. Assuming equal resistance losses due to load current in the primary and secondary windings, we have $q = 0.5$. Now, for full load at 100 per cent power factor, the correction for stray loss due to magnetizing current becomes

$$I^2R \times 2 \times 0.08 \times 0.5 \times 0.125 = 0.01\ I^2R$$

and for full load at 80 per cent power factor,

$$I^2R \times 2 \times 0.08 \times 0.5\ (0.8 \times 0.125 + 0.6 \times 0.993) = 0.056\ I^2R$$

Thus the maximum correction that would be made for 100 per cent power factor load is about one per cent of the resistance loss due to load current, and this becomes about 5½ per cent for 80 per cent power factor load. It appears that this correction is hardly worthy of consideration in questions of efficiency. This is particularly true if we remember that the rise in temperature of the windings while the losses are being measured may produce an increase in the loss as great or greater than the correction which we are considering.

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to the combined exciting and load currents. The total I^2R loss in primary, minus the loss due to the exciting current alone, is

$$(c^2 + 2bc)\ R_1$$

Now

$$b = /I_e/_1 \cos (\theta' - \theta)$$

$$= p \frac{n_2}{n_1} I_2 \cos (\theta' - \theta)$$

$$= p\, c \cos (\theta' - \theta)$$

whence we have: Total I^2R loss in primary loss due to exciting current alone

$$= c^2 [1 + 2\, p \cos (\theta' - \theta)]\ R_1.$$

Adding the loss due to load current in the secondary, and remembering that $c^2 R_1 = q \times$ total loss due to load current, we have:

Total loss due to load current, plus stray loss due to exciting current = total loss due to load current $\times [1 + 2pq (\cos \theta \cos \theta' + \sin \theta \sin \theta')]$

This increase in the copper loss due to temperature rise in the windings while the loss measurements are being made seems to deserve more detailed consideration. Full load current must be sent through the windings for this measurement, and at the start all of the heat produced is stored up in the copper itself. As the temperature of the copper rises, it throws more and more heat out through the insulation into the oil, until the heat thrown out is equal to the heat generated, when the temperature ceases to rise, except as the temperature of the oil rises. The initial rate of temperature rise is therefore fixed by the thermal capacity of the copper and the rate at which heat is generated. The thermal capacity of copper is about 177 joules per pound and the average loss in large transformers is about 10 watts per pound. This gives an initial rate of temperature rise of one deg. in 17.7 seconds, or 3.4 deg. per minute, and an increase in the copper loss of $3.4 \times 0.4 = 1.36$ per cent.

This effect of temperature rise in compensating for the stray loss is illustrated by reference to Table I, showing the results of tests, at the end of the paper by Messrs. Fortescue and McConahey. We see here that the measured loss is larger at high power factors than at low, whereas the correction for stray loss would indicate that it should be smaller. (The stray loss was, in this case, included in the measurement by the method of the test.) This is explained by the fact that the high power factor readings were taken last, and that the loss was increased due to increase of temperature during the tests more than it was decreased by increasing the power factor. These results would have looked very different if the measurements had been taken in the reverse order.

The temperature tests recorded by Mr. Lewis under the heading "Relation between Impedance Watts and Load Losses," in Tables VII and VIII, are, of course, not comparative tests between impedance watts and load losses, but between loads of different power factors, since the exciting current is present in both cases, the only difference between the two cases being that of phase relation between the exciting current and the load current.

Although, as we have seen, the stray loss due to magnetizing current is not ordinarily important from the standpoint of efficiency, still it may be sufficient to account for a considerable difference in temperature rise between two transformers tested together by the opposition method, when this test is made with loading voltage and exciting voltage of the same frequency. The power factor of the load, or circulating current, depending as it does upon the relative amounts of inductance and resistance in the combined impedance of the transformers, is always low, giving almost the maximum correction for stray loss. The correction for one transformer will be positive and that for the other negative, since, while the current lags in one, it leads in the other, the difference in phase of the circulating current in the two trans-

formers with respect to the exciting current being 180 deg. The difference between the copper losses in the two transformers is thus twice the correction for one. There is, of course, a slight compensation for this difference in copper losses, due to the fact that the core loss is somewhat increased in the transformer having the smaller copper loss, and vice versa. The net result, however, may be a difference of two or three degrees in the temperature rises of the two transformers.

Equality of losses may be obtained by using a frequency for loading which is different from that used for exciting. This difference in frequency may be very slight, if desired, maintaining practically the rated frequency both for the excitation and for the load. This is, of course, a necessity for normal core loss, and it is also a necessity for normal copper loss when the eddy current losses are appreciable. The extra loss due to the combination of exciting current and load current will not be present under these circumstances, but only the sum of their respective independent losses.

The mathematical discussion given by Messrs. Fortescue and McConahey, under the second heading, "Theoretical Study of Copper Losses in Transformers," is correctly applicable to mutual inductive circuits in air (with no iron core). However, the values of equivalent resistance and equivalent inductance, given in equations (**7**) to (**13**) inclusive, are not completely expressed. The expressions given are the equivalent values for the nth harmonic only. The equivalent values which must be taken in connection with the value of the total resultant current depend upon the wave form of the current, *i.e.*, upon the relative values of the various harmonics of current. These values of resistance and inductance cannot, therefore, be expressed independently of the current. The complete expression for equations (**7**) and (**8**) would be

$$R_a = R_1 + \frac{\sum\left(\frac{n^2p^2M^2}{(R_2+R_0)^2+n^2p^2(L_2+L_0)^2}\,(I_1)_n^2\right)}{I_1^2}(R_2+R_0)$$

and

$$L_a = L_1 - \frac{\sum\left(\frac{n^2p^2m^2}{(R_2+R_0)^2+n^2p^2(L_2+L_0)^2}\,(I_1)_n^2\right)}{I_1^2}(L_2+L_0)$$

The remaining part of the discussion, if completely expressed, as it must be for any practical application, will be more complicated than it appears in the paper.

I do not agree with the authors that the results obtained in this manner, based upon the assumption that L_1 and L_2 and M are constants, apply with almost equal accuracy to transformers,

where these values vary, not only for different values of maximum inductance, but throughout the cycle for any given value of maximum inductance. This introduces additional harmonics in both current and voltage not taken into account in this treatment, the object of which is to cover the effects of harmonics.

The authors have made no practical application of this mathematical discussion. They state that formulas given in Section 5 of the paper are based upon it, but these formulas take no account of harmonics, and are very easily derived from considera-

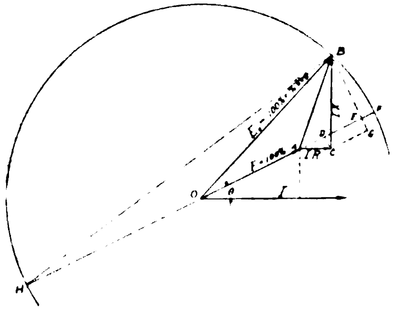

FIG. 1

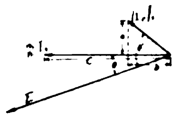

FIG. 2

tions based upon a simple sine wave. Thus, referring to Fig. 1, the formula for regulation is derived as follows:

E_0 is the no-load voltage of the transformer and E the full load voltage at the secondary terminals, so that

$$\text{regulation} = \frac{E_0 - E}{E} = \frac{AD + DF + FG}{E}$$

$$= \frac{I\,R\cos\theta + IX\sin\theta + FG}{E}$$

But $FG = \dfrac{(FB)^2}{FH} = \dfrac{(IX\cos\theta - IR\sin\theta)^2}{2E + 2\,IR\cos\theta + 2\,IX\sin\theta + FG}$

whence

$$\text{regulation} = \frac{IR\cos\theta}{E} + \frac{IX\sin\theta}{E} + \frac{\left(\dfrac{IX\cos\theta}{E} - \dfrac{IR\sin\theta}{E}\right)^2}{2 + \dfrac{2\,IR\cos\theta}{E} + \dfrac{2\,IX\sin\theta}{E} + \dfrac{FG}{E}}$$

and, multiplying by 100,

$$\text{per cent regulation} = \% \, IR \cos\theta + \% \, IX \sin\theta$$

$$+ \frac{(\% \, IX \cos\theta - \% \, IR \sin\theta)^2}{200 + 2\% \, IR \cos\theta + 2\% \, IX \sin\theta + \frac{FG}{E}}$$

Neglecting the last three terms in the denominator of the third term, we have the formula given in the paper, which, though sufficiently accurate for practical purposes, is thus seen to be inexact, apart from any consideration of harmonics.

Mr. Lewis has done the Institute an important service by including in his paper a large amount of data on the extra losses in low-voltage transformers, due to the magnetic leakage field, and in high voltage transformers, due to the dielectric field. It is possible that the values given for extra loss due to magnetic leakage (called stray loss by Mr. Lewis) are, in general, too large, being the total measured loss minus the loss calculated from the measured value of resistance and the current. The increase in temperature during the measurement of this loss gives ordinarily too high a value, as explained above. Moreover, many of the worst cases are seen to be those of magnetic shunt transformers, in which the losses in the shunts themselves are included.

While these losses may be kept to a minimum value by careful design, and are practically eliminated in many cases, yet Messrs. Fortescue and McConahey must agree that commercial requirements as to rating and service, and conditions of design, are often such as to make it practically impossible to avoid quite large losses due to eddy currents.

These cases may be recognized, however, and the calculation of these extra losses usually can be made with sufficient accuracy for a basis of efficiency guarantee. In my opinion, therefore, the common practice of excluding these losses from efficiency guarantees is not necessary, nor desirable.

C. Fortescue: When the paper refered to by Mr. Weed was written the authors had in mind both the eddy current losses the copper, which are easily measured, and the portion of the I^2R loss due to the exciting current which is not included in any of the usual measurements. A portion of the I^2R loss due to the exciting current is included in the core loss measurements and properly so since it is practically constant at all loads. It is necessary to apply a correction to the short-circuit measurement for the other portion of the I^2R loss, but only when the exciting currents are very high, since otherwise this correction is negligible.

Mr. Lewis in his paper tabulates the stray losses and impedance voltages in a number of commercial transformers, and points out that there is apparently no definite relation between these two quantities. I have stated in my paper that in a good design the eddy loss in the conductor can be reduced to a very small value. It might be well to modify this statement by

adding that when high impedance is required the cost of keeping down eddy currents to a low value sometimes becomes excessive. In transformers for furnaces, in which very large secondary currents are required, it becomes particularly difficult to keep this stray loss down. In the ordinary run of transformers, however, this loss can be controlled without materially adding to the cost.

James Burke: I simply desire to call attention to one feature of the paper by Mr. Lewis, which recommends the measurement of the copper losses hot, whereas the universal practise, I think, in this country now on transformers is to take the copper loss at 25 deg., and I simply wish to call attention to the fact that the recommendation of Mr. Lewis is a departure from the existing commercial practise, which is in use in connection with a very large number of transformer manufacturers.

I would like to bring to the attention of the Standards Committee another feature which might be considered in the new rules, and that is, sometimes manufacturers are asked to guarantee the volt-ampere efficiency of transformers, and I have seen specifications asking for the volt-ampere efficiency at 100 per cent power factor, 90 per cent power factor, and 80 per cent power factor, and I think it would be of advantage if the Standards Committee introduced some simple methods of bringing these factors into consideration rather than calling for specific tests under each of these conditions for acceptance tests.

E. A. Wagner: I think Mr. Burke's point about the volt-ampere efficiency is well taken. There has been a very pronounced demand, especially in the railway signal service, for figures giving volt-ampere efficiency. There is nothing really specific in the present standardization rules showing how this shall be done, and I think that the Standards Committee should mention this matter, and state absolutely clear definitions to the meaning of volt-ampere efficiency and also decide as to the effect of the excitation current on these volt-ampere efficiencies.

In regard to these recommendations at the end of Mr. Lewis's paper, I do not think that the exciting current should be deducted and segregated from the core loss measurement, that is, the effect of the exciting current on the copper losses. In a transformer designed for high exciting current, necessarily the core losses have been affected due to that design, and as the exciting current is really a function of the core loss design, I think it should be included in the heading "no-load losses," or else a separate definition made as to the no-load losses which will include the effects of exciting current. Where the no-load losses are to be taken on the primary circuit, according to these recommendations, then it is going to make considerable difficulty in measuring losses on high voltage transformers. We do not measure the core losses on 100,000 volt transformers, on the primary side, we always measure them on the secondary side. The same holds true in the case of commercial transformers, 2200

volts to 110. We measure them directly with a 110-volt wattmeter, and do not attempt to step-up and then step-down.

The last recommendation reads: "On account of the variation with temperature, all losses should be measured at the operating temperature." If the Standards Committee adopts this recommendation, it should be specific as to a definite temperature. As a matter of fact, core losses go down with the increase in temperature, so that it affects the total loss in that way; but it is difficult to hold the temperature steady at any predetermined point if any time is consumed in making the measurements of these losses, and I think, therefore, it is better to specify a room temperature, and take the iron loss or no-load loss at that temperature, and if the full load losses, including copper losses, are wanted, they can be corrected for the rise in temperature.

Charles P. Steinmetz: When the first Standardization Rules were established in 1899, it was stipulated that all losses should be measured at the full-load operating temperature. Transformer losses were included in this rule.

Before that time they had been measured by the manufacturers at the room temperature and the efficiency guaranteed on that basis, and these guarantees were wrong. That question has frequently arisen and transformer designers have come before the Standards Committee and requested that the Rules should be changed to read: "In all apparatus the losses shall be measured at the full load operating temperature, except in the case of transformers, where they shall be measured at the room temperature." It is not desirable to make a specification of this kind for transformers. There is no reason whatever to be seen why this should be done. The efficiency you want to know is that at which the transformer is running, which is at the operating temperature, and not at some fictitious temperature. It is true that it means that you must lower the efficiency guarantees a little, but that cannot be helped. What you guarantee when measuring the I^2R losses at the room temperature, is not the efficiency of the apparatus but a higher value than is actually there.

The I^2R loss of the exciting current should be separated and not included in the core losses. The I^2R loss of the exciting current changes with the load. For instance, if the exciting current is 10 per cent of full load current, then at no-load the I^2R loss of the exciting current is 1 per cent of the primary I^2R loss, and conversely the primary I^2R loss at full non-inductance load is 100 times the I^2R loss at no-load. But at full inductive load the exciting current increases the load current by 10 per cent, and so gives an additional primary I^2R loss of 21 per cent, and that means at full inductive load the primary I^2R loss is 121 times as high as at no-load. Obviously therefore, the I^2R loss due to the exciting current must be considered separately and not included in the no-load losses.

Leo Schuler: I call your attention to the fact that when you measure the efficiency of the transformer at room temperature, instead of working temperature, it does not mean necessarily a very great difference in the efficiency, because the copper losses, of course, are lower, but the iron losses are higher, especially with alloyed iron.

James Burke: I want to correct any misunderstanding of what I said. I am not advocating measuring the transformer losses at room temperature. I was simply calling attention to the difference between the commercial practises of today and the recommendations.

Charles F. Scott: In regard to the word "stray," if I am not mistaken, laboratory manuals present the "stray power" method of measuring efficiency which is taught to the student as a very definite thing. Stray power is about everything that I^2R does not include. The power to drive a motor is measured at no-load, and what is not I^2R is stray power.

I asked this morning one of the designing engineers of one of the large companies, whether the term "stray power" was used in his organization. He said he did not know that it was. We come here and find the word "stray" used indiscriminately to cover about everything which cannot be accounted for.

The moral of this is that one of the chief duties of our Standards Committee is in the matter of definitions. Here is a term "stray," that certainly needs to be defined.

J. M. Weed: I think Mr. Wagner's objection to measuring the core loss from the primary side is based upon an erroneous definition of the primary side. The primary side is often the low-voltage side, as the transformer may be used either for raising or for lowering the voltage.

J. E. Saunders: I notice the recommendation is that transformer losses are to be measured at operating temperature. I want to know what this operating temperature is. We are hanging transformers where it is 130 deg. fahr. in the shade in the summer time, and they are hanging out all summer, and we are hanging them in another place where it goes as low as 30 to 40 deg. fahr. below zero, in the winter time, and those are the operating temperatures, so I want to know why we should not substitute room temperature for operating temperature.

C. Fortescue: The operating temperature, I think, is defined as the temperature at which the transformer will operate at the standard room temperature of 25 deg. with full load, at 100 per cent power factor. In transformers we base our rise on the average temperature of the coils as measured by the rise of resistance method. We do not indicate the temperature of the hot spot. In transformers there is a very slight difference between the average temperature of the coil and the maximum temperature, on account of the small temperature gradients through the insulation, and coils, etc.

J. M. Weed: There is one point which I think should be recognized by the Standards Committee in laying out their

rules, and it may be that some of the members present might wish to discuss the matter if it is brought out specifically, and that is the question of cooling after the load is taken off the transformer. This, of course, applies to all electrical apparatus. It is practically impossible to get the resistance measurements at once, of course, and it is a fact that the apparatus is cooling after the load is taken off until such time as the resistance can be taken. It is possible, as has been brought out in some of these papers, to make corrections, but this matter of correction is always an uncertain matter, and will involve complications, and it would possibly be better to specify a time limit within which the resistance measurement should be made, recognizing the fact that the actual temperature at the instant that the load is taken off is a little higher, but considering it on the same basis as the hot spot that we cannot find.

A Member: There exists a method for finding the real temperature which is much easier than to find the hot spot. You have only to know exactly the moment when you really take the load off the transformer. Say that you press a stop watch at this moment, and then take two or three readings afterward, plotting a time-heat curve, and extrapolate that curve, you get the correct value the moment that you really took the load off the transformer.

L. T. Robinson: In connection with the remarks of the last speaker, I would say if those who are interested will refer to the paper which was read here yesterday by Mr. Chubb, they will see that the extrapolated value will not always be correct. Under some conditions the part where you are taking the temperature by resistance goes down after a while, and then it begins to go up by transfer of heat from some iron part or something else that is hotter. It may be useful to use extrapolation sometimes, but it must be used with caution, otherwise you may get a large error.

J. M. Weed: In determining the temperature by extrapolation the results are very uncertain, for the reason that slight inaccuracies in the readings modify the shape of the curve very much. The point that you decide upon as the initial temperature is very much influenced by errors in the first two or three points of the curve.

C. Fortescue: I agree with Mr. Weed that the method of extrapolation by means of a curve is very uncertain and brings in a large personal factor. It may be necessary in some cases to use such methods but it would be better if some quicker methods could be devised for measuring the resistance of the windings than those at present in use. One thing that can be done in using the Kelvin bridge or the Wheatstone bridge is to have them set for the expected reading; in this way the final adjustment can be made very quickly. A measurement made in this manner is so quick that I believe only one or two degrees are lost. A matter of one or two degrees has but little effect on the operation

of a transformer, and therefore I think measurements obtained in this way are sufficiently accurate.

Paul M. Lincoln: A definite question has been asked as to what temperature shall be used in calculating the copper losses of transformers and other apparatus, and I think this question is one which requires a definite answer and one which should be fixed by the Standardization Rules when promulgated. It seems to me that is best answered by adopting the suggestion made in Mr. Lewis' paper, namely to base it upon the operating temperature. But that operating temperature should be taken above a standard air temperature, and in my opinion that standard air temperature should be taken at 25 deg. cent. Therefore, the copper loss in a transformer should be calculated at the temperature at which it will actually operate when the surrounding air is 25 deg. cent.

W. C. Smith: In connection with the question of losses just brought up, and also referring to the statement of Dr. Steinmetz this morning, in which he said that the customer is most interested in losses at the operating temperature, there is another question regarding efficiencies which should be touched upon by the Institute, and that is the question of efficiencies at fractional loads. The present rules imply that the efficiency at a given load should be based on the operating temperature at that load. In the case of fractional loads, this imposes a serious burden on the manufacturer, one that is not complied with nowadays or asked for. Fractional efficiencies are guaranteed at the same temperature as the full load efficiencies, so I believe that the new Institute Rules should state clearly that all efficiencies, both for full load and fractional loads, should be based on the full load operating temperature.

J. M. Weed: I would suggest that it ought to be satisfactory to specify the efficiencies of the transformers at temperatures at which they are guaranteed to operate at full load; that is, with standard room temperature, if you guarantee a transformer for 35 deg. cent. rise, with a room temperature of 25 deg. cent., base the efficiencies of that transformer on the losses at 60 deg. and if you guarantee 50 deg. cent. rise over 25 deg. cent. room temperature, you guarantee your efficiencies on the basis of 75 deg.

W. C. Smith: Inasmuch as I brought up this point, I would like to go on record that I concur fully with the two gentlemen who have just preceded me—in my opinion, all efficiencies should be based on the full-load guaranteed operating temperature.

G. K. Kaiser: Referring to the question of operating temperatures, it appears to me that the regulation as well as the efficiency should be based on the temperature which the apparatus assumes when operating continuously under load. That is, the regulation at various loads and power factors should be determined from the *load losses* at operating temperature and the reactance of the transformer.

(c) Brush Losses

W. B. Brady: Referring to the paper by Messrs. Edgecomb and Dick, the brush manufacturers are very much interested in the subject of brush losses and we are very glad the Institute has taken up this matter. We have been working on the development of brush tests for more than six years but we have been handicapped by the lack of apparatus that would give us consistent results. Then, again, as we have developed our own apparatus the results we got were applicable to that apparatus and only under the exact conditions of that test. This is due to the number of variables and losses that are in a certain combination under the conditions of that test. By having these losses more definitely separated and understood we may be able to get a definite basis to make our results comparable. One of the best ways I know of is to standardize the brush testing apparatus and I hope this can be done in the very near future. It will be a decided step in brush development which will be of great assistance to engineers.

Leo Schuler: I ask whether any experiments have been made in this country with regard to the influence of the current flowing from the commutator to the brush, in relation to the friction. It is rather surprising, but it is a fact, that friction is somewhat influenced by the current on the brush. I cannot see the reason for it, but there may be a molecular attraction on the surface of the commutator.

B. A. Behrend: In regard to Mr. Schuler's question, whether the coefficient of friction depends on the current in the brush. If an experiment is conducted on an electric motor or generator, very many vitiating factors enter into it, so that it would be impossible to say that the presence of an electric current is responsible for the alteration or change of the coefficient of friction, and I ask Mr. Schuler whether he means that under stationary conditions such change or variation in the coefficient of friction is obtained?

Leo Schuler: I do not know whether in those cases it would affect it or not. What I know is this: With a slip-ring arrangement, driven by a small synchronous motor, just sufficient to drive the slip-ring with the brush on it, that synchronous motor falls out of step the moment you put current on the brush. That seems to indicate an increase of friction due to the current.

There is another reason. When you work a machine idle, that means excited, but no current on, then you hear a certain noise produced by the friction of the brushes on the commutator, and you will notice quite a pronounced alteration of this noise, when you put current on; there seems to be no other explanation for this than that there is another coefficient of friction when the current is on the machine.

B. A. Behrend: May I ask whether it is not possible that this additional power required in your synchronous motor is due to current induced in your slip-rings and in your brush. You would expect such induced currents, would you not?

Leo Schuler: But I cannot see how power is taken from the motor for these eddy currents.

B. A. Behrend: That seems to be the critical point at issue; if there is any possibility of this applied power having to come from the synchronous motor, it would not be charged to coefficient of friction.

Leo Schuler: I think if there are induced currents in the slip-rings then the power to produce these currents can only be taken from the source of current which is going through the slip-rings, but not from the motor driving the slip-ring.

B. A. Behrend: I would not be so ready to endorse that statement; it does not seem to me to be absolutely evident that is so. Perhaps some one else has thought more about that point, and can give us some information regarding it. I ask Mr. Lamme whether it is not possible that the creation of a magnetic field by an electric current and its consequent passing through the slip ring would not account to some extent for the falling out of step of the synchronous motor driving the device. I do not know that this is the explanation in the specific case cited, but it seems perfectly plausible to assume the existence of such magnetic field through which the slip-ring has to cut at a certain definite rate of speed which would put an additional load on the driving synchronous motor. I may be mistaken in my explanation, but it is entirely reasonable.

W. B. Brady: Answering the question about the influence of current on the coefficient of friction, Messrs. Martindale and Berkeley in their paper have indicated that the coefficient of friction decreases very materially with increase of current. We tried that under four different grades of carbon on the slip-ring, simply a band of copper mounted on a pulley, and measured the friction in that way. It decreased very materially with increased current.

A. H. Freeman: We have made no particular tests to determine the effect of current density on coefficient of friction, but my observation has been, on some temperature results, it may have that effect which Mr. Brady speaks of, the coefficient of friction drops slightly with increased current densities. In the paper by Messrs. Edgecomb and Dick, I see that they recommend a set of constants for representing the difference between the surface of the test apparatus and the surface of cast-iron, steel, bronze and various other materials.

Alexander Gray: About a year ago I started some students on experimental work on brush friction and the results they obtained were so erratic that no satisfactory conclusion could be drawn from them. Recently I started up the same apparatus and found that the coefficient of friction could vary 300 per cent in half an hour. The friction force was measured by a spring balance at the end of a beam which was supported on ball bearings concentric with the shaft of the motor and which carried two brushes at opposite ends of a diameter. At the

start, the pull on the scale was about one pound; at the end of half an hour the pull had gone up to two pounds, and the temperature of the brush, measured by a thermo-couple placed within 1/16 in. of the rubbing surface, also increased. The brushes then began to chatter, the temperature rose very rapidly to several times the previous value and the pull on the scale went up to 3.5 pounds. One of my assistants came into the laboratory at that time; he was smoking and blew a cloud of smoke on the ring; the scale reading went down immediately to 2 pounds, the chattering stopped and the temperature dropped considerably; the chattering did not commence again nor did the pull on the scale reach the value of 3.5 pounds for about one minute. Afterwards, as a matter of curiosity, I ran my finger across the ring surface, the pull immediately dropped to two pounds, the chattering ceased, and both took about one minute to rise again to the original value. A piece of waste was then put in contact with the running ring and was left there for half an hour at the end of which time chattering had ceased and the scale reading had come down to one pound, and then although the waste was removed, the pull did not increase in two days for which length of time the apparatus was kept running continuously. A bunsen flame was then applied to the ring and although the friction pull decreased, the decrease was very small. A little vaseline was then put on the ring and the scale pull came down to a smaller value and stayed there.

After a thin film had been ground from the brush contact it was possible to reproduce the above cycle of operations.

In case there should be any misunderstanding, I may say that the brush was a modern one, and had a highly polished surface. The film on the ring was not something I put on myself, but was inherent in the brush.

The above results seem to me to be of such importance that I would be tardy in standardizing certain coefficients of friction for certain standard machines, in fact I consider the proposition to be very objectionable. Brush friction depends largely on the design of the holder and on the workmanship put into the brush mechanism. If I buy a machine with a certain guaranteed efficiency I want to measure the efficiency or losses in some way or another, and shall not be satisfied with something calculated by the manufacturer from constants, even although they are standardized by the Institute.

If the brush friction is measured when the brushes are newly ground a certain result is obtained; if the machine is then run for several hours the friction loss may increase 300 per cent, but by running a piece of waste across the commutator surface for some time the friction loss can be reduced again. This being the case I would suggest that the new rules make some recommendation as to when the friction loss shall be measured, whether before or after the heat run and also as to whether or not the manufacturer should be allowed to clean the commutator before he measures this loss.

Comfort A. Adams: I think we will all agree that the whole question of satisfactory operation of commutating machines, as to the commutator and brushes, is one which depends upon a very great many details not only of manufacture but also of care and operation. There are many variables involved, and it is difficult to lay down general rules. It is not anything you can theorize much about one way or the other. I will simply state what I have found to be the most successful method of operating commutating machines from the purely practical standpoint. This applies to modern, good quality commutating machines, with brushes such as are ordinarily supplied. Start with the commutator in perfect condition, as far as it can be made so, and the brushes well fitted; then watch it very carefully for the first few days, or possibly a week. During the first day of its operation be very sure to keep the commutator so clean and in such condition that it will not cut. I assume, of course, that the machine does not spark enough to burn. After the polished condition has been once established, very little care will keep the commutator in good operating condition without any lubrication. In fact, my experience has been that there is more danger with lubrication than without, after the commutator is once thoroughly well polished and is in good working condition. It is not sufficient, in the case of a freshly ground commutator, to clean it off once and let it run for a day or two without any care at all. It is only after it has become thoroughly polished that it can be allowed to go with occasional care, and the principal thing is to keep it clean and dry. There is a little lubrication in these brushes, but much of it is apt to gum up the commutator and a little sparking will cause the coefficient of friction to rise very rapidly.

Alexander Gray: The work presented to us in these papers is excellent and we ought to be grateful to the writers for the amount of work they have put into them. I know what the measurement of the coefficient of friction on brushes means. The point we are concerned with, however, is not the angle of the brushes—we are not going to test for that; we are looking for a suitable performance test for brush friction loss and instructions as to how to make it.

As Professor Adams says, the proper thing to do is to take care of the commutator for two or three days and then let it run; but if you tell the manufacturer you want the machine to run for a week before you test it, he will probably increase the price. The point I want to make is that we might hurry this first part of the business by cleaning off the film which is deposited and so allow the brushes to take the bedding sooner than two or three days. If we can do that, let us standardize it; if we cannot do it, let it alone.

In regard to the suggestion that the smoke was a lubricant, it is ingenious and it may be right. The smoke may also act as an

abrasive which cleans off the film of carbon; the same man blew on the commutator when he was not smoking and it made no difference to the friction loss, so that we can eliminate the question of moisture.

B. G. Lamme: Mr. Schuler has raised a point about the effect of current on brush losses. I will say that under some conditions current may have a great effect on the total losses in connection with collector rings. In the case of very heavy rings carrying very heavy currents, the magnetic field set up by such currents, if cut by the collector rings, may be such as to cause very heavy eddy current losses in the rings themselves. In the case of a 2000-kw. unipolar generator with which I am familiar, in the preliminary tests, one-half of the rings on the machine were made of steel, instead of bronze, and on the test with normal full load current under zero voltage conditions, the measured loss was approximately 200 kw. higher than when all the rings were bronze. Our investigation showed that the excess loss was due almost entirely to eddy currents due to magnetic action, and was not due to brush contact. The loss was almost entirely in the rings themselves. With bronze rings there was some loss, but not more than a few per cent of that found with the steel rings. In this case, therefore, the losses varied with the current, and such losses were carried by the driving motor.

Apparently there are two opposite opinions regarding this variation of friction with the current, one claim being that it is reduced with the current and another that it is increased. It seems to me that an action other than the eddy currents above described may also be present, namely the influence of the direction of current on the brush contact itself. Our test with the unipolar above referred to, showed that where the currents passed from the brushes to the rings, the rings tended to take a good glaze, and but relatively little attention was required in the way of cleaning; whereas, where the current passed from the rings to the brushes there was a continued tendency to burn away the surface of the rings and to increase the resistance of contact. Apparently, one of these actions should give less friction loss than the other, and possibly in the conflicting opinions cited, the different results may have been due to different arrangements of testing which did not take the direction of current into account.

In the question of brush friction losses, especially on new machines, the condition of the commutator itself must be taken into account. Until commutators are well "seasoned," they are liable to show high brush friction losses. The binding material in the commutator mica may ooze out to a very slight extent, and "gum" the commutator slightly. This will increase the friction enormously, but as it is obviously impossible to thoroughly season every commutator before shop test, it is necessary to put the commutator in the best possible shape for such test, with the understanding that in practise, after it is well

seasoned, the losses will doubtless decrease materially. That is one of the handicaps on the manufacturer.

Alexander Gray: Should that seasoning be done by the manufacturer or should that seasoning be done by the purchaser? If we adopt certain standard friction coefficiencies, then it will have to be done by the purchaser. If we do not adopt these standards, the manufacturer will be at liberty to get his commutator into any kind of shape he likes, and we will test it when in that shape, and then the manufacturer will have to do the tinkering to the machine. Most of us would be quite satisfied, on an order of twenty machines, to get a test on one. to test all of the twenty would be somewhat of a nuisance. We do not expect elaborate tests on small machines.

R. B. Treat: The efficiency of direct-current machines will in the majority of cases be found to meet the specifications at the time of factory tests. Whatever reduction of brush friction occurs on the commutator after erection accrues to the advantage of the customer.

Commutator seasoning time may vary all the way from zero to six weeks or more but the manufacturer's brush friction figures are usually based on results he can obtain in factory test.

One disturbing feature of brush tests on collector rings is the chattering. This often results from a slip ring loosening when it becomes warmed up. Some recent tests were conducted with taper shaft and ring fitted with a follow-up spring.

Many cases of very rapid brush wear were cured by the substitution of rings that could not become loose even where the original ring could not be declared " loose " by hand examination.

Brush friction probably decreases as the current increases. The general result of many tests indicates this conclusion.

W. F. Dawson: I would suggest in explanation of Professor Gray's trouble with brush chattering that the trailing angle was incorrect and that a reduction in such angle would have stopped the chattering. The increased friction coefficient observed was probably due to brush surface picking copper.

Alexander Gray: I am personally doubtful about a leading brush not chattering so much. My experience has been largely with machines having trailing brushes, and if these are rotated in the opposite direction the brushes will generally chatter.

B. A. Behrend: As Mr. Lamme has stated, there are so many mysterious factors about the commutator and the brushes and in the operation of commutators, that he has no hesitation in frankly saying so. Professor Gray, who has had wide experience in the operation and design of direct-current machines, has come to the same conclusion.

I do not think it is possible to adopt a specific brush angle. We have to run at all commutator speeds up to 8000 ft. These angles have to be adjusted, and it is often necessary to undercut the mica on some commutators; in other words, every possible

and suitable means must be resorted to in order to make the commutator run true and to eliminate the chattering of brushes. Chattering of brushes is due to some sort of harmonic disturbance, and it becomes cumulative at certain speeds and under certain conditions. The disturbing periodic force can occasionally be eliminated, and though the natural period of vibration remains, the external cause of chattering having been eliminated, the chattering has been stopped.

Under these conditions it seems to me it would be folly, as we are interested here in the subject of standardization, to lay down rules as to the coefficient of friction, as to the angle of the brushes, and as to a great many of these things which the manufacturer himself does not know anything about as yet. I was once talking to the chief draughtsman of one of our large manufacturing companies, and I asked him if he had any standards. He said, " Why, Mr. Behrend, we have thousands of them." We are going to have thousands of standards if we have to lay down such rules at the present time, because we do not know enough about these things. Every day the field changes. The commutator of to-day is a very different piece of apparatus from what it was ten years ago.

F. D. Newbury: I believe Mr. Gray has been the only speaker who has kept to the point at issue in the discussion of the brush loss papers. The work before the Standards Committee, as Mr. Gray said, is determining how to measure brush losses and not how to operate machines.

In regard to brush friction, I do not believe that this measurement presents a very difficult problem, not so difficult as the determination of the other brush losses touched on by Mr. Wilson losses of commutation, voltage drop, etc. Brush friction can be measured directly on the machine at the time the machine is on test at the manufacturer's plant. If such determinations do not fall within reasonable average values, it means one of two things; that the manufacturer must go to the expense of putting the commutator in first-class shape, which not only means seasoning so that there are no high bars or high mica, but running the machines a sufficiently long time to secure the dark brown glaze every one likes to see on a commutator; or that the customer accepts such average values, appreciating the fact that the commutator on shop test is not in the best condition. In the case of other brush losses, involving voltage drop, I believe we will be forced to an assumption of average drop per brush, or some such method as will be discussed tonight in determining additional losses.

L. E. Underwood: Regarding the running of brushes trailing I am inclined to think that it is possible to run them trailing with success at slightly greater angles than 15 deg., possibly at 20 deg. or even 25 deg., although that depends a great deal upon the speed and condition of the commutator.

As for running the brushes leading; it is undoubtedly true

that for different speeds of commutator it is necessary, in order to get best results, to run a leading brush at different angles. That being the case, the practical application of leading brush holders on the same machine which is used for various and sundry speeds, seems to be quite a problem. I do not see exactly how the problem will be solved.

T. M. McNiece (by letter): The determination of brush losses is exceedingly difficult under any conditions. The actual values or results secured by tests are greatly influenced by the state of the surfaces of the sliding contacts. The duplication of these surface conditions on brushes and commutators is exceedingly difficult and it is a problem to determine whether or not these factors are sufficiently alike in successive tests to warrant definite conclusions.

In the paper by Messrs. Erben and Freeman, attention has been called to the effect on friction of various angles of inclination between the brushes and the commutator. In connection with this, a formula is given for calculating the watts lost through brush friction and this formula is applied to a specific case.

Some question may be raised in regard to the accuracy of this formula. The effect of varying the angle of inclination of the brush with respect to the commutator may be well illustrated by the use of a force diagram. With holders of the box type, four forces may be said to be acting upon the brushes: (1) the pressure, P, applied to the brush in the direction of its axis; (2) the frictional force, W, at the brush contact, acting in the direction of rotation; (3) the normal pressure, N, between the brush and commutator; (4) the reaction H, of the brush holder. The line of application of this force is normal to the sides of brush and holder. The amount and direction of P and the direction of W are known and the amount of W determined by the test as made. The angle B is the angle between the brush and the normal to the commutator at the point of intersection between the axis of brush and the circumference of commutator.

If a force diagram be now constructed it will be seen that

$$N = \frac{P}{\cos B} + W \tan B$$

The formula in this form applies to those cases in which the brush is trailing. When the brush is leading the formula becomes

$$N = \frac{P}{\cos B} - W \tan B$$

The coefficient of friction may then be calculated from the formula $F = \frac{W}{N}$ where F is the coefficient of friction.

Substituting in this equation the values of N, for both trailing and leading brushes, we find that

$$W = \frac{F\,P}{\sin A - F \cos A}$$

for trailing brushes and

$$W = \frac{F\,P}{\sin A + F \cos A}$$

for leading brushes, where A is the angle between the brush and the tangent to the commutator at the point of intersection of the axis of the brush with the commutator.

When the brush is trailing the normal pressure is found to be composed not only of the projection of the applied pressure, P, but also of the added projection of the reaction, H, of the brush holder. The forces, P and F, combine to make H of considerable moment in the trailing brush. The normal component of this latter force may be sufficiently great to hold a brush on the under side of the commutator without any spring tension and against its own weight.

The cause of the greater friction in the trailing brush may be said to lie in the greatly augmented normal pressure on account of this wedge action of the brush between the holder and the commutator. As indicated in the formula

$$W = \frac{F\,P}{\sin A - F \cos A}$$

for trailing brushes, there is a certain value of the angle A for each value of F, where theoretically W becomes equal to infinity. This is at the point where the tangent of the angle, A, is equal to F and the reaction, N, at this instant is infinitely great. Before this point is reached the holder or brush would yield or the braking action would stop the rotation of the commutator.

In the leading brush, the action of the force W tends to decrease the wedge action of the brush as well as to decrease the applied pressure P. As a result of this, the normal pressure is greatly decreased with a consequent reduction in friction. The formula in the paper under discussion would therefore take the form

$$W = \frac{P \times F \times V \times 746}{33000\,(\sin A + F \cos A)}$$

Sufficient work has not been done along these lines to enable us to say how closely results may be expected to agree with the theoretical formula or what correction factors may have to

be applied in order to make this equation of working value. A later report will be made as soon as definite results are secured.

There is always a certain degree of eccentricity which may cause a very slight rise and fall of the brushes in the holders and it is possible that the slight friction between sides of the holder and the brush may affect the results to some extent. The clearance between brushes and holders may also exert some effect on these quantities.

Another factor which would undoubtedly have a considerable influence on this point is the rigidity of the holders, especially when the brushes are trailing. The brush holders on a friction testing machine should be rigidly constructed and supported, or they will have a great influence on chattering, which will seriously affect the frictional readings. A study of these conditions leads to the conclusion that trailing brushes demand much more rigid holders than leading brushes.

In view of the form taken by this formula, it is recommended that the characteristic friction tests made on any grade of brushes be made with the brushes in a radial position. The proper friction at any angle can then be calculated from this formula. This will simplify the tests very greatly.

L. R. Berkeley and E. H. Martindale (by letter): There is one phenomenon which has not been mentioned in this paper which is worthy of much investigation, namely the variation of friction with different current densities. The accompanying figures are an average of the results obtained on four different grades of carbon brushes, with comparatively high coefficient.

Amperes per sq. in.	Coefficient of friction
0	0.81
20	0.59
40	0.41
60	0.34
80	0.30
100	0.27

These results were obtained on a copper slip ring at a pressure of 2 lb. per sq. in. (70.4 grams per sq. cm.) and at a peripheral speed of 1000 ft. (305 m.) per minute, with brushes set in a radial position.

From the table it is seen that the coefficient of friction at 100 amperes per sq. in. (15.5 amperes per sq. cm.) is one-third as great as when no current is passing through the brush. The writers believe this may be due to a graphitization of carbon particles by the small electric arc which carries the current between the brush and the commutator.

This phenomenon cannot be explained by change in temperature as artificial heat will not produce the same effect, in fact, heat usually tends to increase rather than decrease the friction.

After the current is shut off it requires from three to fifteen minutes for the friction to rise to the normal zero current value.

T. M. McNiece (by letter): As stated by Mr. C. E. Wilson, the contact drop losses are so intimately associated with others which may be termed commutation losses, that their accurate separation seems to be practically impossible at this time.

In practise the I^2R loss at the brush contacts is often so much greater than the loss which would be indicated by test on a slip ring or short-circuited commutator at the rated current density, that the tests may be said to give almost no indication of the loss to be expected at this point. It seems very proper to separate such losses from the brush losses if possible, and since they depend entirely on certain details of design and construction of the machines, the pure brush losses should be determined and increased by a certain factor which might be termed a commutating constant. This constant would be peculiar to the type of machine upon which the brushes are to be used.

It seems advisable in making contact drop tests, to make all standard tests upon radial brushes. In view of the great changes produced in the normal reaction between brush and commutator, by running the brushes at various angles, and since this normal reaction also has great influence on contact drop, it would seem that these effects might be determined by the use of suitable constants.

The decreased friction secured by operating the brushes in a leading position cannot be said to be a net gain, as it may be assumed that under the decreased effective pressure, the contact losses will be increased to a certain extent.

The variations introduced by running the brushes at different angles are merely those which would be produced by changes in effective pressure and area.

From an analysis of the conditions accompanying the determination of brush losses, it seems that in friction losses as well as voltage losses, the most satisfactory methods for securing these results will be those in which the characteristic tests are applied under the most simple conditions and the results of these standard tests modified by the application of factors to be determined by the actual condition of operation. This system would result in simpler and more effective standardization of testing methods.

(*c*) Generators, A-C. and D-C.; and (*d*) Errors of Tests

John L. Harper: There are statements in the paper by Messrs. Foster and Knowlton which seem to warrant further consideration, reference being made especially to the first paragraph in the summary. The authors describe four methods of determining losses in each of which it will be noted a different result was obtained.

These losses are measured for the purpose of determining the efficiency of the generators. Now, if the efficiency of a generator could be determined by the use of several different methods, which under the same conditions gave different results, this one generator at the same moment would have several different

efficiencies, depending upon the method used for determining the losses or upon the wording of the contract under which it was furnihsed, or whether the designing engineer had been so incorrect in his computation that it was necessary to boost the efficiency by a choice of methods.

It may be conceded that efficiency might vary with time or conditions and that errors of measurement of energy and losses may exist. But it is undoubtedly true that a generator can have only one efficiency at one time.

I therefore believe that the Standardization Rules should be explicit and frank in the statement that the efficiency of an apparatus is a fact, and not a variable result depending upon the method of determination.

The gentleman who prepared the articles on efficiency in the old rules probably never intended that a manufacturer would claim the approval of these rules, in requiring a purchaser to accept and pay for apparatus as meeting efficiency requirements when such so-called efficiency determination was based on the shop measurement of certain segregated losses; when this same apparatus after being set up and tested by a method closely resembling the " circulating energy " method, (mentioned in the paper as the most correct of the determinations) was shown to have additional losses which brought the efficiency down to about 3 per cent below the specifications.

As one of that part of the membership of the Institute which is not connected with the manufacturing interests, it is not my desire to put forward such methods of measurement of efficiency as will cause undue or unnecessary expense to the manufacturer, thereby increasing overall expense which is added to prices which customers must pay; and it is far from my intent to assume that it would be right or proper to require small and stock apparatus to be sold under any special efficiency requirements.

It is only my desire to ask that in the further consideration now being given the Standardization Rules, the word efficiency be considered to mean true efficiency; and the Institute gives its approval, for the purpose of determining efficiency, only to such methods as measure all the loss (within the limits of correctness of measuring instruments), and also such methods as represent a minimum probable error; and that any other commercial methods are accepted only as approximates of efficiency, and their approval given on that basis. What I want to bring out is that methods in which all the losses are not determined should not be used for efficiencies, but should be used in determining commercial approximations of efficiency and which are approved on this basis. Therefore, in my opinion the drafters of the new rules should make clear what is intended by the term efficiency, and then so generalize the methods of determining the losses, that facts cannot be evaded, and still full leeway may be obtained for the adoption and use from time to time of more

correct methods of determining all the losses in electrical apparatus.

It is unfortunate that the classes of apparatus chosen by Messrs. Foster and Knowlton for these determinations are such that the difference in the losses determined by the segregated loss method and the "circulating energy" method appears to be slight, for in my own experience, gotten in the Niagara Falls district in connection with apparatus from the smallest to the largest sizes, it has come under my observation that in certain classes of machinery a difference of two or three per cent may be found in the losses as determined by the manufacturers according to the segregated loss method and that found after erection by methods which measure all the losses with minimum error and of the general form called "circulating energy" methods in the experiments of the above authors.

In general, in small apparatus the exact determination of efficiency is of little interest to the purchaser. In the larger, and often the special apparatus used in the Niagara vicinity, exact determination of efficiency is of vital importance, often representing the payment or non-payment of hundreds of thousands of dollars, and it is hoped that the Institute will not approve such methods of determining losses that the purchasers of this class of apparatus will be obliged to oppose the standards approved by the Institute, but may rather be assisted by them in obtaining correct efficiency determinations of any of their electrical apparatus.

Leo Schuler: In the German Standards Committee we have recently discussed very carefully the question of what we call "additional losses." We have tried to get some method for taking these losses into consideration, but so far we have failed. We have considered the proposition contained in your present rules, which takes one-third of the short-circuit loss, but this, I understand, is only intended for synchronous alternators. You do not give any hint how to check additional losses, in regard to direct-current machines or induction motors.

I have looked forward with great interest to what is to be said about this question here, but as far as I can see, it will be very difficult indeed for the Standards Committee to condense these papers into certain rules to be applied to all kinds of machinery, and I should strongly advise you, if you do not arrive at a very definite method of doing it, and I do not think you will, to leave the additional losses out altogether and do as we have decided to do, that is, call the efficiency measured by the separate loss method the "conventional efficiency" or something of that kind, an efficiency which is somewhat lower than the real efficiency, but you do not know how much lower it is. This proposition is not very good, but I think it will be the best you can do.

R. E. Hellmund: I wish to make a few remarks about the paper on "Losses in Commutating Machines," especially

referring to direct-current machines. The hope is expressed in this paper that it will be possible to get a constant percentage which should be added to the I^2R losses in order to take into account the stray losses. This, of course, would get the average efficiency slightly more correct, but it certainly would not show the merits of the various machines. The reason for this is that the stray losses are very numerous in direct-current machines, in fact in all commutator machines.

In the paper referred to, the authors mention only the commutation losses and the loss due to flux distortion. These are some of the most important losses, but there are a large number of others, which in some motors may be rather large. We have first the regular iron core losses, which, of course, are little influenced by the distortion, but even these may be somewhat influenced by the interpole flux which exists only at load. The same is true with regard to the core losses in the teeth. Here, as the paper mentions, the distortion of the main field is of importance, but the interpole flux may also add some losses at load. Further there may be some extra losses in the surface of the interpoles, which are due to the fluctuations caused by the passing of the armature teeth. Then we have similar losses in the surface of the main poles, which also change with the distortion.

Further, if the relation of the teeth to the pole face has certain proportions, the total reluctance of the magnetic path changes, and this, of course, will tend to set up fluctuations in the main flux which in turn will set up eddy currents in the frame casting, as well as in the short-circuited coils under the brushes; this, of course, means again losses. It has also been shown that considerable losses may occur in the commutator bars, and with very heavy currents and heavy bars this loss may be appreciable in some machines.

Finally, we have some losses which seem to me rather important, and which exist even with ideal commutation. The paper mentions that commutation losses exist if the commutation is not perfect. These losses are important, but even if the commutation is perfect, the current direction in the armature changes; in other words, the current in the armature conductor is alternating current, and we know very well that in alternating machines, with heavy conductors, the losses in the conductors are rather large. There is no reason why we should not have the same losses in the armature conductors of direct-current machines. These losses are due to the fact that the current sets up fluxes across the slot and these fluxes reverse when the coil passes the commutator zone, thereby inducing voltage and consequent eddy currents. Then we have certain losses in the armature conductors under the pole tips, in case the saturation in the teeth is very high. This is due to the fact that the reluctance of the teeth just under the pole is very high, while the reluctance of the teeth next to the pole, with small saturation, is rather low. The difference will cause a certain flux to pass

across the slot, and since this is a changing flux there will be eddy losses. These losses were mentioned this morning. Finally we have the losses in the bands and coils.

It can be seen, with such a variation of losses, that it would be hardly fair to assume that the stray losses are similar in all machines, and I think that an attempt should be made to get at these losses separately. This, of course, can only be done by building machines which have only one of these losses at a time to any appreciable amount, and making tests along that direction.

In connection with commutator machines, it seems important for us to consider not only the direct-current commutator machines, but also the single-phase and three-phase commutator machines, for standardization. Some work along this line is especially desirable, because certain losses cannot very readily be tested in case of alternating-current motors, and in order to avoid complications it is always good to have some rules as to how they should be taken into account, when ideal methods of testing are not known. While the influence of the field distortion in the single-phase motor is usually not so important as in the direct-current machine, we have other losses. For instance, we have alternating current in all windings and consequent losses, and also the conditions are rather complicated due to the fact there is a main flux and a cross or transformer flux. Since it is impossible to get a combination of the two fluxes as they actually exist, without having the load on the machine, there is at the present time no method of testing the core losses at all.

W. J. Foster: The two papers which I wjsh to discuss are those by Messrs. Olin and Henderson and by Messrs. Foster and Knowlton. The first contains diagrams showing connections of machines that must be considered in connection with the second paper, as that is not as complete as it should be. Now, reference was made this afternoon to the "circulating energy" method which was advocated by the Messrs. Olin and Henderson, as a safe, reliable and accurate method, and a practicable one, where two identicual alternating current generators or motors are available. By referring to their paper, you will find a diagram given for connecting together two alternators for an input-output test. It consists in placing the machines back to back, with a coupling so arranged as to give an angle in one direction for one machine, and in the other direction for the other machine, and so that they will operate as generator and motor under certain conditions of load and power factor, and any conditions of load and power factor may be obtained by changing this adjustment. There is a direct-connected motor, preferably a direct-current motor, such as would be used in determining core losses or the friction and windage. It is not necessary to have the motor direct-connected, as it can just as well be belted.

The determination of load losses by this method I have found, by a number of tests, involves no more difficulty, and is just as

accurate as the determination of windage or core losses by the same method. The only objection that might be made to it, possibly, is that one machine is operating as a generator and the other as a motor, and we must assume that practically the same effect is obtained in the motor as in the generator in the matter of the additional losses due to the presence of the current in the primary. In working up the results, the open circuit core loss in the generator is taken at the normal voltage, plus the *IR* drop, and in the motor, the normal voltage minus the *IR* drop. That method is compared by Messrs. Foster and Knowlton as to the results obtained with two or three other methods that were tried. One of the other methods that the authors undertook with considerable confidence that it would prove the practicable one, was the no-load phase characteristic, for the reason that when an alternator is running with a very weak field, or very strong field, just so as to have full load current in the armature at the normal voltage, it seems probable that the same conditions exist, as far as producing the stray load losses are concerned, as under normal load. The trouble with that method is the measurements which must be made by wattmeters, first with the lagging current, and then with the leading current, and that the results must be compared with another value that is almost as great, namely, that obtained at the minimum current input. There are many little errors in the readings when you are reading a comparatively large quantity, which may amount to a very decided error when considered with reference to a small quantity that is the difference of two large quantities. All such errors are eliminated in the " circulating energy method."

This particular method of " circulating energy " must not be confused with a form of operation in testing that consists in coupling together two alternating current generators or motors in phase, supplying the necessary energy to run them from a third generator and obtaining the current desired by adjustment of excitation. In this method we do not obtain the correct conditions of potential, field excitation, etc., whereas in the one I have just described all conditions are normal and there is just that one difference between the machines, one is a motor and the other a generator.

The authors have given a great many data, these data having been available and having been selected out of a great mass of data of tests made on machines extending back for fifteen years. We do not have data available on this new method, because it has not been in use. The data given in these tables were available because the Institute has had a rule that for what it has called load losses, a short-circuited core loss should be made and one-third of that taken. By referring to these tables you will see that in some cases the second column under " core losses " shows in certain case the short-circuited core loss to be as great as 1.5 per cent of the full load energy of the machine, and would affect its efficiency 1.5 per cent, and that in certain cases the

short-circuit core loss is greater than the I^2R loss, and in certain other cases greater than the open circuited core loss, and in some greater than either; but by taking one-third of that, it will reduce the efficiency from one-quarter to one-half per cent, but you will also notice that the general average of all the machines is rather low, something like one-half of one per cent, and when we take one-third of that, it amounts to only one-sixth of one per cent, so that the machines have not been badly punished in the past, you may say, where the efficiency has been determined by taking into consideration one-third of the short-circuited core loss.

The input-output method was not tried on any one of these three machines, but in connection with other machine tests were made by the input-output method, as has been referred to by other speakers. Such tests involve great difficulty and do not inspire confidence, since the tests obtained at different times by different men give such widely different results; whereas, in the "circulating energy" method, the results agree with one another every time you make the test, as closely as they do in the open circuited core losses or determination of windage.

A speaker this afternoon referred to some of the machines given in the tabulation, as having very low short-circuited loss, and that it was unfortunate that machines had not been selected that had high short-circuited loss. We feel the same way, but there did not seem to be available any machine that had a high short-circuited core loss, and, therefore, we ran one of these machines single-phase, and greatly to our surprise, the loss there loomed up large, as you will see by referring to Fig. 11 of Foster and Knowlton's paper. Comparing Fig. 11 with Fig. 9, which refer to the same machine, you see that the short-circuited loss amounts to 3 per cent of the single-phase rating of the machine; whereas, when operating three-phase, it amounts to a little less than one-half per cent.

What we wish to suggest to the Standards Committee is that they do not discard these short-circuited core losses until further data is accumulated, as we think it probable that the entire short-circuited core loss should be taken. Another evidence that we have that the entire short-circuited core loss should be taken is what we have obtained from the heating of the machines. There are now available a great many data on the enclosed type of machines, not only steam turbine generators but water-wheel generators. It is a comparatively easy matter to measure the temperature rise of the air passing through the machine, when it is operating under load; then run the machine on open-circuit at over-voltage at a point where the losses are equal to the combined segregated losses as determined by the ordinary method. The difference in the temperature rise of the ventilating air under the two conditions is the measure of the load losses.

F. D. Newbury: The question before the meeting is not whether all losses should be taken into account in determining

the efficiency, but the best method of determining the true efficiency. The operating engineer can have no legitimate objection to any method that takes all losses into account, whether that method is based on the determination of the separate losses, or on the direct measurement of input and output.

Mr. Robinson's paper shows the difficulty, if not the impossibility, of obtaining an accurate, true efficiency by the direct measurement of input and output, even in the most favorable case, where both can be measured electrically. Even with his well-known ability and unexampled facilities, the extra load losses are very elusive. The load losses as shown in curves 1 and 3 depart markedly from the known law of their variation with load. The reasons for this are well brought out in the paper by Messrs. Chute and Bradshaw. One probable reason for the obviously incorrect results shown in curve No. 3 is the unusually high efficiency of this set. With a combined efficiency at full load of 91.3 per cent by separate losses, the efficiencies of the separate machines would have to be 97 per cent for the alternating-current motor and 94.5 per cent for each 500-kw. direct-current generators. These are unusually high efficiencies for machines of this class. The combined efficiencies of 88.7 per cent in the 1000-kw., 250-volt set more nearly represents commercial figures.

If the correctness of this statement be granted, then it follows that more accurate efficiencies will be obtained from the separate loss method (including all losses) than by the most careful input-output tests.

Alternating-Current Machines. Three recommendations for estimation of extra load losses are made:

1. That open circuit core loss and calculated I^2R loss be increased by a factor 1.1 to cover the extra load losses.
2. That the measured short circuit load loss be taken as the load loss.
3. That one-half measured short circuit load loss be taken as the load loss.

The relation between the load losses measured under short circuit conditions and those existing under actual load is too complicated to permit any general statement to be made that will apply to all generators. Consequently, it is very difficult to make one rule apply to all machines. Load losses may be roughly divided into three classes:

1. Increase in armature core loss due to change in flux distribution.
2. Eddy and hysteresis losses in adjacent metal parts due to the stray field from armature current.
3. Eddy current loss in the copper conductors.

In generators having well divided armature conductors and small flux per pole (including all small generators and all engine type generators) the load losses are, undoubtedly, mainly due to

flux distortion. For example, the 150-kv-a., 900-rev. per min. generator referred to by Olin and Henderson; the measured load loss for one generator at full load was 0.61 kw. and at 1¼ load 1.55 kw. The measured short circuit loss (including I^2R loss) is 2.3 kw. at normal load amperes and 3.7 kw. at 1¼ normal load amperes. The I^2R loss calculated by Olin and Henderson is 2.27 kw. at full load and 3.55 kw. at 1¼ load. The measured short circuit load loss is, therefore, practically zero at full load and 0.15 kw. at 1¼ load. The calculated I^2R loss is based on an assumed temperature which may or may not have existed during the short circuit test, as pointed out by Brainard. Comparing the measured load losses at full load with the load losses at short circuit, the actual load losses at full load are seen to be greatly in excess of those at short circuit. The difference is, undoubtedly, due to the increased tooth loss under load, due to armature reaction. This same increase in measured load loss at full load over the corresponding loss at short circuit is shown in the 110-kv-a., 900-rev. per min. generator referred to by Foster and Knowlton.

In large medium speed generators involving moderate flux per pole, the load losses are probably due to flux distribution and to increased stray field.

In high-speed steam and water turbine generators, the load losses are a combination of all three classes.

Single-phase generators are in a class by themselves, due to the pulsating armature field in distinction to the rotating armature field existing in polyphase generators.

I believe that a combination of the correcting factor advocated by Olin and Henderson and the direct measurement of load losses at short circuit advocated by Foster and Knowlton will be necessary. Moreover, different correcting factors will be necessary for different frequencies and for single-phase generators. The correcting factor is undoubtedly nearer the truth with small moderate speed machines and of slow speed engine type machines. For large moderate speed and all turbo-generators the actual load losses are probably equal to the measured losses at short circuit judging from the data submitted by Foster and Knowlton. For single phase generators, obviously the measured short circuit losses are nearer the true load losses than those obtained by a factor based on polyphase machines. I agree with Mr. Foster we should measure the load losses directly by the "circulating power" method. That method, however, is greatly limited by the fact that two duplicate generators are necessary, and it is an expensive test to make, so that it can only be used where the size of the machine and importance of exact efficiency demands that care and expense in the testing work. In spite of the complicated relation existing between actual load and short circuit conditions, it is interesting to note the close agreement between load losses calculated by the two methods as presented by Mr. Knowlton in his discussion. It is also interesting to note that the load losses by any

method of calculation are small when expressed as per cent of the machine output. In 25-cycle generators, the average is well under one-half per cent, and in 60-cycle generators the average is well under three-fourths per cent.

Direct-Current Machines. Comparing the Olin-Henderson paper and the Erben-Page paper, the results are seen to be in fairly close agreement for the 470-h.p., direct-current commutating pole motor in the former paper and the 500-kw., 720-rev. per min. commutating pole generator in the latter paper. The correction factor for the 470-h.p. motor is 1.27 at full load while it is 1.29 for the 500-kw. generator at full load; while at $1\frac{1}{4}$ load the former is 1.37 for both machines. In both machines the load losses are very closely proportional to the square of the load.

The non-commutating pole machines follow an entirely different law in regard to the variation of load losses with load, and the same constants cannot be applied to both classes of machines, particularly at light load. Other factors undoubtedly must be used for other classes of machinery.

To conclude:

1. Efficiency will be most accurately determined from the separate measurement of losses, including the extra load losses.

2. The extra load losses may be determined in the case of all machines by direct test when two duplicate machines are available and the importance of the matter warrants the testing expense.

3. They may be determined approximately in synchronous machines by established correcting factors and by the measurements at short circuit. I agree with Mr. Foster that we should not abandon the measurement at short circuit, because whether that does or does not represent full load conditions, it is certainly a very good indication, and will bring out faulty machines, particularly when the extra load loss is an eddy loss in the copper, which is a factor not always foreseen.

4. They may be determined approximately in commutating machines by established correcting factors. Correcting factors will vary with the ratio of no-load and full load maximum inductions, which may be approximately calculated. That difference in the ratio is well brought out by the different conditions existing in constant speed machines and variable speed machines, and the reason for the difference in the correcting factors which Mr. Erben mentioned this afternoon.

5. The determination of additional load losses may be made only within relatively wide limits without causing a variation in efficiency greater than the minimum variation obtained with an accurate input-output test.

E. F. Collins: To those who have not had long and close contact with electrical testing, it may seem that input-output methods are best to adhere to, and that all this discussion concerning the stray load losses, brush friction, contact loss of

brushes, etc., should cease. On the other hand, one who has conducted many input-output tests knows that only by the most careful arrangement can correct efficiencies be secured through the use of this method. This includes the best of power conditions, as regards its freedom from fluctuations, and skilled men as observers. Sometimes as many as 20 observers are required to obtain simultaneous observations in a single efficiency test. In order to secure the same accuracy in efficiency determinations very much less error in observations is allowable than where losses alone are being observed directly. Many sets of observations must be taken, so that the probable error will be reasonable. The computation of these observations requires the very greatest attention and diligence on the part of the calculator on account of their multiplicity. Many meters of precision must be used. Heavy currents usually associate themselves with the method, especially in the larger units, and much care and judgment must be exercised to protect against unknown influence of stray fields. Thus one could continue to enumerate almost indefinitely precautions which accompany a successful determination of efficiency by input-output methods. Many such sources of error do not exist in using no-load methods, and where they do exist they do not influence final results to the same extent.

Mr. Robinson has shown well by tables and curves what may be done in determining efficiency by input-output methods. He has indicated somewhat the price paid for his results, and this price may be now and then justified. In general testing, however, I think there is little justification for the input-output method.

It has been said this afternoon that if we are to get at the true efficiency by segregated losses, we should include all losses. I agree that we ought to have approved methods of test which will allow of a determination of all losses, as well as a segregation of of such losses when required. I believe that certain methods exist and have been employed that do determine such losses, at least for certain classes of apparatus, such as direct-current rotating apparatus and alternating-current synchronous apparatus.

At the present time standard methods exist for determining core loss with brushes at electrical neutral. Measurement can readily be made of bearing friction and windage, also brush friction, at no-load. The I^2R loss of the armature and fields may be readily and accurately figured for any load. The contact and brush resistance may be calculated from the contact loss curves, or it may be measured directly under operating conditions, as I will indicate later. Having determined these losses by no-load methods, the question naturally arises whether or not all the load losses are accounted for.

A method which may be relied upon to answer this question for alternating-current synchronous apparatus is the "circulating energy" method described by Messrs. Foster and Knowlton.

The objection to this method is that it involves two duplicate machines. As to its accuracy, however, in accounting for all losses, there is no doubt. It is, of course, desirable to have a method which may be applied with the same accuracy to single machines. Hence, the turning to a consideration of the short circuit core loss as compared to the stray load loss measured by the circulating method.

I want to refer to the diagram given in Mr. Robinson's discussion, to illustrate that an equally efficient method has been employed for direct determination of stray load losses in direct current machines. Incidental to this method of determining stray losses, and in view of the discussion this afternoon of brush losses, I want to call to your attention that in this method we have actually measured the brush contact I^2R loss under operating conditions, through the use of insulated brushes, as shown. It may be of interest to say that a number of such determinations have been made in this way and they agree closely with standard curves of contact resistance loss that have been derived upon a dead commutator.

I want to call attention also to the fact that if a change in brush friction occurs under load, this method takes account of it. From such tests I have had indications of change of brush friction with current. Some of those discussing the subject this afternoon held the opinion that this friction decreased with current, others that it increased. I am sure from the tests I have made that both are in a measure correct. In some cases I have observed an increase with current, in others an indication of a decrease with current.

It will no doubt require much investigation before practical methods may be devised that will permit of ready use for determining stray load losses for all classes of apparatus. In the meantime, perhaps, the use of certain empirical constants may be necessary in determining true efficiency by segregated loss method. In that event, however, I believe that some such direct method of measurement of these stray load losses should be employed as a basis for the value of such stray load losses, and correcting factors, and identify them with the designs with which they correspond.

B. G. Lamme: I wish to speak on the subject of load losses from the standpoint of a designer, and not as a member of the Standards Committee. Since I first looked over the Institute rules, I have always objected to the methods given in these rules for the determination of load losses, and also the method for determining efficiency, as it was an approximation that did not represent the facts closely enough to suit me.

Now, in comparing any of the methods of making tests for the stray losses, we should not take good machines when making such comparisons, because, in well proportioned machines, the extra losses may be relatively low. We should pick out machines which we have reason to think have abnormal extra losses, and

in that way we may find so large an extra loss that errors in the determination are of smaller proportion.

For many years I have been concerned in the measurement of load losses, and have frequently taken up the calculation of them just to determine the possibilities for the application of correcting factors, which would fairly accurately cover the extra losses. Such calculation is a long and complicated process in many cases, but when carefully carried out, I obtained some astonishingly close results in those cases where I had reasonably accurate data to compare with, but I will say that the accuracy of these results was, in one way, very discouraging; for in some cases, the larger items in these calculated extra losses were such that they apparently bore no relation whatever to the measurable quantities; that is, the data we could obtain by any simple direct measurement had no relation to the extra losses, and therefore our separate measurement of losses gave no direct quantitative indication of the value of these extra losses.

In a very well proportioned machine, I will venture to say this—that I can review the design of that machine, and I can then estimate, off-hand, the load losses as closely as they would be given by any of the methods suggested this evening. Still, these methods may show closer, on individual items of extra loss, yet, in my rough estimate, I would allow for some losses not touched on at all by any of the methods proposed for approximating the extra losses. In taking any of these methods of approximating the losses, you may get results which look very good from the general standpoint, but if you look at the results closely from the design standpoint, you are likely to see something in them that you know is inconsistent with the design—and that throws doubt on the whole result.

Taking the method of determining losses by short circuit. In many machines there are extra losses due to saturation of certain parts of the circuit, and these do not appear at all in the short circuit test, and therefore, in such cases, it is purely an accident if the measured short circuit loss happens to coincide with the extra losses in the machine.

It looks to me as if all of these methods, including the input-output, under commercial conditions, must be considered as only rough approximations. I have seen a good deal of testing done by the input-output method, and I have never been satisfied with the results unless I knew before-hand what the extra losses ought to be. I have seen tests repeated four or five times until the results happened to give a value that everybody agreed upon as being reasonably correct, but in fact, this particular result may not have been any closer than any of the others. It seems to be largely a question of keeping up the testing until everybody is satisfied or tired out. That is how much confidence I have in it.

We must look at this input-output testing from two different standpoints. The man who tests the machine from the instrument

standpoint may have absolute confidence in the instruments and in the men who make the tests for him, but the result which he thinks is satisfactory or correct may appear to be decidedly incorrect to the man who designs the machines, for he may know that the stray losses indicated are inconsistent with his design.

It is possible that some correction factor, even if an assumed one, is better than to do away with any allowance for the extra losses. The great trouble with the old rule of segregated losses was that the engineering public knew that these did not represent the total losses, and did not want to accept the resulting efficiencies, because there was something left out. Now, the total extra loss usually represents only a small value compared with the measurable losses, and even if omitted, the error is ordinarily rather small, although, in extreme cases or under very special conditions, it may become quite appreciable. In some cases, this omission of the load losses has been made up by the direct assumption of a certain per cent reduction in the efficiency, as, for instance, one per cent. Such assumption unquestionably averages closer to the true result than omitting the stray losses altogether. But it seems to me that this is largely a commercial consideration, and, from an engineering standpoint, all we can do is to state what the measurable losses are, and then possibly indicate roughly the total extra losses, but not make them the subject of any guarantee, as we should not guarantee what we cannot measure.

(To be continued).

MIDWINTER CONVENTION PAPERS

GROUP III. METHODS OF TESTING APPARATUS FOR PERFORMANCE.

(a) GENERATORS AND INDUCTION MOTORS.

Comparison of Methods of Loading Large A- C. and D-C. Generators and Synchronous Converters for Factory Temperature Test, by F. D. Newbury.

Comparison of Methods of Making Load Tests on A-C. Generators and On Induction Motors, by E. F. Collins and W. E. Holcombe.

Notes on Method of Making Load Tests on Large Induction Motors, by A.M. Dudley.

(b) TRANSFORMERS.

Load Tests on Transformers, by J. J. K. Madden.

Sources of Error in Transformer Tests, by W. M. McConahey and C. Fortescue.

Discussion on Group III Papers—"Methods of Testing Apparatus for Performance". New York, February 28, 1913. (See Proceedings for February, 1913.)

(Subject to final revision for the Transactions.

(a) Generators and Induction Motors

A. E. Averrett: I would say in regard to the results in the Collins and Holcombe paper, that I made some tests at the same time, and the results obtained with the first two motors (two 20-h.p. motors) are somewhat erratic; one of the motors was somewhat unusual, in that the rotor had a completely closed slot. We ran these tests through in a hurry and I believe the results ought to be discounted.

The 50-h.p. 900-rev. tests show remarkably close results, 24 deg. by the actual load, and 26 deg. by the approximation method. The next test, the 100-h.p., shows very close results, 24 deg. by the full load, and 26 deg. by the approximation at normal load, and at 25 per cent overload it shows 34 deg. rise by load and approximation.

The next machine, 250-h.p., was a machine we selected in the test which we were in a hurry to ship, and we did not test it as carefully as it should have been tested. Before we used this method at all, several years ago, Mr. Collins conducted a number of careful tests, running over six or seven machines, and sufficient time was taken to test them out thoroughly. The agreement between the compromise tests, as we called them—that is, the full-voltage, no-current test, and the full-current, low-voltage test—was very close, and we thought that it was as safe as duplicate tests under approximately full load conditions. They were remarkably close, and as a result we adopted that method for big machines.

This seems to hold on a wide range of machines, machines with a high core loss and low copper loss, or the reverse.

Commenting on Mr. Dudley's paper, the reverse rotation method; on the first test the normal rise was 25 deg. and on the circulating current method, the reverse rotation method, I believe he calls it, it was 38 deg. There is a considerable discrepancy. That machine, probably, is a machine with a small core loss. It is a wound rotor and undoubtedly the eddy losses in the copper at double frequency must have developed to heat the machines up so much.

In the next table the reverse is the case, that is, the core loss is large; I suppose that should be correct; they have given it different currents, the actual load temperature is quite a little higher than the circulating. In the next group the actual is a little higher than the circulating. In the table which follows, the actual is higher than the circulating, and it seems to me, from my own experience, that this reverse rotation method will hold closely in a machine where the losses are largely copper, and the core loss very small, but in a machine where there are no eddies, and where the core losses are high, I

do not see how it can hold. It happens in the average run of machines that the copper loss is quite a little higher than the core loss, and undoubtedly the double frequency in the secondary teeth, even at low density, does give enough additional loss to approximate full load conditions; but I believe it is only applicable to a very narrow range of machines.

R. B. Williamson: A load obtained by means of synchronous motors running idle, and operating the generator at zero power factor, makes about as satisfactory a compromise test as can be obtained.

In it the conditions are worse than under actual load, because the field current is greater, but it shows what the heating will be under the worst possible conditions. This method can be made to approach actual conditions closer by using alternately leading and lagging currents, but this makes the test more complicated.

Where this test cannot be applied, the next best is the open circuit test at such over-voltage as to make the total losses in the machine approximately equal to what they would be under load. The distribution of the losses is different, but it gives a test of the field heating, and also some idea as to the core heating under actual load. A test of this kind is especially useful for turbo-generators where most of the loss is in the core, and in windage and friction, and where the stator copper losses are comparatively small. A short circuit test, by itself, does not show much, unless there happens to be local heating due to stray losses of some kind.

R. E. Hellmund: With regard to induction motors, I agree with Mr. Averrett that the method of testing induction motors with reversed rotation can only give results with machines where the core losses are comparatively low. However, the large majority of machines are of that kind, and the test is so convenient, as compared with others, that I think it should be legalized within certain limitations. We have used it a good deal, and although we know its limitations, we find it a cheap and convenient test for many cases. Altogether, in induction motors, any heat test that takes principally into account the copper losses will be satisfactory in most cases, due to the fact that in all but high speed machines the core losses play a comparatively small part in the heating, except possibly in motors with very high speeds. In the ordinary run, the core losses are a small percentage of the total losses; but not only that, the seat of the core losses is in such close contact with the frame and other large cooling parts that often a doubling of the core losses in medium and low speed machines can hardly be found in the heating, while any additional copper losses appear rather rapidly.

B. G. Lamme: I will say something on the general subject of testing. The manufacturers of electrical apparatus make what might be considered four different kinds of tests. In the first

place, a test is sometimes made which is primarily for the purpose of obtaining data for design purposes. Such tests may be made on exceptionally good machines upon which the manufacturer wants special data. These tests are of no particular advantage to the purchaser, or to anyone, in fact, but the designer.

A second kind of tests is that made by the manufacturer's engineers, to determine whether the machine meets a specified guarantee. A third set of tests is what might be called a witness test, to prove to the customer that the machine meets the guarantee. The second and third kinds of tests should really be covered by one test, but, in many cases, this apparently cannot be done, as the test which indicates to the designer that the machine is all right does not always appeal to the customer as being a satisfactory test. A designing engineer and the customer's engineer look at the machine from two different view points. The designer judges the test from his experience with similar kinds of machines upon which he has obtained data, and he bases his opinion partly on experience. On the other hand, the witnessing engineer wants full proof that the individual machine being tested meets the guarantees, although this covers a lot of work which has already been carried out by the manufacturers many times on similar machines. What we would like to get is some recommended standard test or tests which would eliminate a lot of this double testing and the disagreements which naturally accompany them.

A fourth class of tests may be called routine tests. For instance, if a great number of duplicate machines are made, only one of these may be tested completely, while, on the remainder, certain tests are made which show only certain characteristic data, which, compared with the more complete test, indicate that the machine is necessarily a practical duplicate in performance.

Leo Schuler: I want to ask whether it is the intention to make this equivalent test a part of the Standardization Rules? I think that would be rather dangerous. There are natural differences between the results obtained by these equivalent tests and by the real load tests. I think, however, it would be a very good thing for you to make an appendix to your Standardization Rules, in which certain methods of artificially loading machines and transformers are recommended, and in which the probable sources of error are indicated. This would facilitate and strengthen the position of the manufacturer if he could show under the authority of the American Institute of Electrical Engineers the probable error would not be more than such and such an amount.

B. G. Lamme: I want to say that Mr. Schuler's statement represents exactly the attitude of the Revision Committee on this subject. The Committee wishes to recommend, if possible, certain tests as the advisable ones, and to state the disadvantages and probable errors of each, so that in any test that is specified

and carried out, it will be known just what errors are liable to be found. At the present time, the difficulty lies in the fact that there is a continual disagreement over these errors in testing. If the fact can be brought out conspicuously that certain errors are inherent in our methods, it would eliminate some of our troubles.

E. I. Chute: The simpler the method of testing the more accurate and consistent will be the results obtained. Results that cannot readily be duplicated are oftentimes worse than useless as they may lead to erroneous conclusions. The intermittent temperature tests proposed while very pretty in principle are quite difficult for a tester to conduct in such a manner as to duplicate results. Unless there is some very decided advantage gained by the suggested methods, and this seems contrary to our experience, the zero power factor test with overexcited field when possible and the circulating current test in other cases, should be recommended.

Paul M. Lincoln: This question of substitute tests or compromise tests, is an important one to the manufacturer, because the tests, practically all of them, are made in his own shops where the facilities for testing are usually limited when it comes to the question of applying real power to the machines. The amount of power which can be so applied is limited, both on account of the fact that the power may not be available, and also on account of the fact that the method of application, such as is used in the final installation, is not usually available at the time of test. I am in perfect accord with the opinions which have been expressed to the effect that the best substitute test is one where the machine operates at zero power factor. That is the best substitute test, and is certainly one which will give as high temperatures as the machine will give at any other power factor load.

That is all very well for such machines as the manufacturer is prepared to load up in this manner but the modern machine often goes beyond the ability of the manufacturer to supply the apparatus necessary for this test. When we are dealing with machines of 10,000 to 20,000 kv-a., most manufacturers are not prepared to supply loading back facilities for so large capacity, and therefore it becomes important to have a test which we can substitute in place of the zero power factor test and it is the effort to find such a test that has led to the paper by Mr. Newbury and also the paper by Messrs. Collins and Holcombe. The most hopeful line of investigation seems to point to some method of alternate open circuit and short circuit operation that will give results in heating, equivalent to the actual load test. The results so far reported would indicate that the alternating cycles of short circuit and open circuit will give a test which is sufficiently close to actual results as to make it one which may be safely referred to in our Standardization Rules.

F. D. Newbury: I do not like to disagree with my colleague, Mr. Lincoln, but I must take issue with him in his statement

that the intermittent short circuit or open circuit test is to be placed next to the zero power factor lagging test. In my own experience I have found the direct-current circulating test to be preferable for machines for which it is suitable, to any other test. The only limitation to the use of the direct-current circulating test is the presence of solid material in the rotor. There is, of course, a field, which is stationary, with respect to the revolving field, so that any solid material in the revolving part will have rather severe eddy currents generated in it. I think that is the explanation of the very high rotor losses shown in some of the tests given by Messrs. Collins and Holcombe. But that is a limitation that is easily foreseen, and the effect can be directly measured by observing the input to the driving motor with the direct current in the armature, and without the direct current in the armature, so it is a perfectly safe test to apply. You know when you can safely apply it, and when you cannot. The objectionable test is the one in which you cannot predict abnormal condition and cannot, therefore, interpret results when you obtain them. The difficulty with the intermittent open and short circuit test, I think, is one that Mr. Chute brought out, which is the difficulty of exactly duplicating results and the lack of experience, so far, as to the proper relative open circuit voltage and short circuit current. In the large generator we tested the core temperature was about 10 deg. higher by the intermittent test than by other available methods—the circulating or zero power factor methods. That indicates that the theoretical condition of equal losses is too severe a condition for that method of test, or at least, for certain generators. After it has been found that it gives erroneous results in one generator it raises the question as to its reliability in the next generator, and prevents its adoption at least until we have attained as large a number of years of experience with the method as we have with the other methods of testing.

Leo Schuler: We spoke a good deal yesterday about additional losses, or "stray losses" or "load losses," or whatever you might call them. Several very interesting papers have been presented upon this question, but, nevertheless, no simple and easy method has been suggested for calculating these additional losses for every machine, and calculating them so as to convince the consulting engineer. Even if Mr. Lamme is going to guess this additional loss, I do not know whether the consulting engineers will be convinced by that method. If you make an equivalent test of any kind whatever, it will never be possible to take these additional losses into true consideration, because you do not know them, and this will always be a drawback in these equivalent tests.

A. J. Porskievies: In two-phase machines it is not always feasible to get open delta direct-current heat runs because circuits may not be arranged to provide for circulating currents. Also in single-circuit machines it may be difficult to arrange for

circulating currents, both from electrical and mechanical standpoints. There are enough two-phase machines in demand to give this consideration some weight.

Carefully made open- and short-circuit heat runs ought to give reliable results provided the equipment does not permit of the circulating method.

F. D. Newbury: The point in regard to two-phase and three-phase generators is taken care of in either the zero power factor test or the direct-current circulating test. Of course, the method of test is more familiar to us in the case of three-phase machines, because all large machines at the present time are three-phase. The only condition necessary for the application of the direct-current circulating test is that you can form a closed circuit, and open this at a point at which the voltage is zero for the introduction of the direct current. This can be done with a rectangular connection in a two-phase generator as well as with delta connection in the three phase so that the direct-current method is just as applicable to two-phase as three-phase.

As to the point brought out by Mr. Schuler, in regard to the stray losses; while we cannot measure these stray losses, some of these methods do take them into consideration. In the zero power factor method all of the stray losses are present, except the difference due to the different flux distortion at zero power factor and operating power factor. Of course, the distortion is less—strictly speaking, there is no distortion at absolute zero power factor. In some generators, notably some slow speed engine type generators, we can obtain higher temperatures on energy load than at zero power factor.

Leo Schuler: I do not consider the zero power factor method an equivalent. I think it is the real method.

F. D. Newbury. I have no comment, then.

Alexander Gray: Regarding the direct-current circulating test; I used to think it was a very good one until I came across a machine recently which on the test floor had a temperature rise of 40 deg. cent., but, when put in operation, got so hot in the center that the machine had to be rewound. It so happened that the design was faulty, because the machine had deep conductors and a core 32 in. (81.28 cm.) long, and the direct-current circulating power test did not disclose the eddy current losses or the hot spots in the machine. It is for such large machines that we want an equivalent test. Moderate size machines can be tested by the zero power factor method, but large waterwheel and turbine units take a large amount of current from the power house, and must be tested by some other method.

B. A. Behrend: A very convenient test in connection with the testing of multipolar alternating-current generators was suggested by me ten years ago. It consists in the division of the field circuit into two circuits of equal number of poles. Hundreds of these tests have been on machines of all sizes ranging from 50 kw. to 5000 kw., and they have been satisfactory. The

method has been termed the "split-field method," and it is fully described in a paper read before the International Electrical Congress at St. Louis in 1904. It is entirely practicable. For instance you can take a machine like the 40-pole Manhattan generators and, by tapping the field circuit in one point, and passing different currents through the two field circuits, you can obtain a zero power factor load on that machine. The heating is very nearly the same as under zero power factor. The method eliminates mechanical vibration as the armature reaction balances the strength of the magnetic poles. The regulation corresponds to a power factor zero. The chief objection to all equivalent tests lies in the proper adjustment of the field excitation. If you want to use the direct-current circulating test you have to know what field excitation to use. If you want to use an intermittent test, a core loss test alternated by a short circuit test, you must also know what short circuit current and what excitation to use in both tests, and in order to know that, you require a knowledge of the zero power factor regulation, and a method for deducing from this zero power factor the regulation at other power factors under which you desire to make the equivalent test. With all these difficulties before you, I think you will agree with the Chairman in his statement that it would be unwise to embody equivalent test rules in the Standardization Rules, because it would open up all doors to discussion and disagreement. I fear that in order to accomplish anything you will have to adopt Mr. Lamme's method, which I consider, personally, an ideal method, viz., the method of guessing, as I can guess a great deal better than most people can test, and so can Mr. Lamme, but we have difficulty in making others believe that we can do it.

R. B. Williamson: I believe that the short circuit loss curve is the best indication we have of the various stray losses. These stray losses are due to a number of different effects such as eddy currents in conductors and currents set up in unlaminated parts, particularly of enclosed machines, such as turbo-generators. Mr. Lamme brought up the point of the stray loss also bearing a relation to the core loss. If a machine has a poor core and a high open circuit core loss it will be reflected in the short circuit core loss curve. That is, a machine with a bad open circuit core loss will also show a bad short circuit core loss. The short circuit core loss curve thus takes account of nearly all of these items entering into the stray loss, and as shown by Mr. Foster, the total short circuit core loss checked up very closely with the measured stray loss.

In most open machines the stray loss is small if the machine is properly designed, and in machines where it is sometimes considerable, such as in turbo-generators, it can be easily shown that part of it exists in certain parts of the casing. It seems to me that if such losses are shown by the short-circuit loss curve they must be present on regular load. I would therefore be in

favor of taking the whole of the short-circuit core loss in estimating efficiency as being nearer the truth than the one third part as recommended at present by the Rules.

F. D. Newbury: No method of loading, as such, will in itself bring out the internal heating; that must be secured by better methods of temperature measurement. I have had very deeply impressed on my mind this fact in connection with some large generators which were tested by the zero power factor method. They came through finely, and everybody thought they were good machines, and yet, when some of the coils were taken out, in order to ship the stator in halves, the interior of some of the coils were found to be very seriously damaged by heat, so much so that the generators had to be rewound; and, to bring out a point mentioned by Mr. Wilson, a comparison of the short-circuit loss before they were rewound and after they were rewound did not indicate any material difference. It was simply a case where the armature conductors were supposed to have been laminated and insulated from each other, but in a few coils the insulation was defective. Certainly that cannot be detected by a method of loading, or in all cases by a method of temperature measurement.

H. M. Hobart: In substitute methods, one wants to get as nearly as possible to the same heating in each principal part of the machine as one gets when the machine is in regular service and it is carrying its rated load. One wants the same number of heat units per hour, or half hour, or ten minutes, developed in each part as under the conditions of rated load. By the intermittent open circuit and short circuit method you get exactly that, provided you make each cycle of operations occupy a sufficiently small number of minutes. In very large machines it is generally arranged to have the complete cycle of operations occupy fifteen or twenty minutes. But you can take even greater intervals and taper them off toward the end of the run into very short periods. In any case, I cannot see that there is any flaw whatsoever in this method, except that alluded to by Mr. Schuler and others, that there is a little uncertainty about the flux distortion under the different conditions, and that difficulty is met in all the other methods and sometimes to a much greater extent than in this method.

If in any case there is any startling discrepancy between the results obtained by this intermittent method and by any other method, the suspicion lies on the other method. However, the intermittent method has the disadvantage of requiring the expenditure of mental effort in planning the test in advance and this has usually served to bring it into disfavor. But certainly the time of an engineer, is well spent in mapping out the scheme on paper, and ascertaining the appropriate conditions for the test. As an ultimate standard I cannot conceive of anything better than this test, where the power available is limited.

I do not believe that the difficulties of carrying out this test

are nearly so great as is at present thought; it is simply lack of experience and chronic aversion to anything new. I believe it only requires time for this scheme of testing to win out on its merits, but it seems to me a pity to wait for several years, for the natural process of evolution, to bring this method to the front. When it was first brought to the attention of engineers, there was a great deal said about the loss of time in switching over from one connection to the other. That can be done practically instantaneously, as is now generally admitted. All sorts of other objections were brought forward but now it seems to me the only one on which engineers fall back, is the fussiness of making these preliminary calculations, and this objection, it seems to me, is magnified unduly. I trust that careful consideration will be given to the merits of the alternate short-circuit and open-circuit tests.

Leo Schuler: I wish to endorse fully the recommendation which Mr. Hobart made with regard to his method. It is certainly a very excellent, and at the same time a very convenient method, and I can say that this method has been applied to a great extent, in the works with which I was connected. As, however, the short-circuit losses are fully taken into account by the Hobart test the temperature measured in this way will be somewhat higher than that which could be expected in the real load run; this is, of course, all right for the shop test, but you must distinguish between the shop test and the official test, and if you have not much margin on the temperature allowed, then you would naturally hesitate to make this Hobart test as an official test.

Stuart L. Henderson: The intermittent short-circuit and open-circuit test does not work out very well from a practical standpoint on large machines and it is on this type that the test should have its greatest application. The chief difficulty is to get reliable temperatures. During the time the machine is on short circuit the iron temperatures decrease and when on open circuit the copper temperatures decrease. This necessitates cutting down the time of the cycle towards the end of run to obtain uniform temperatures and consequently a man does not have time to get around to read all the temperatures before the cycle is changed. This practically means putting a man on each thermometer to obtain satisfactory results.

J. J. K. Madden: The switching arrangement is not as difficult as would at first appear. Tests were made on a 500-kv-a. unit by the use of two interconnected switches, but it was unnecessary to adjust the field current when applied.

Charles P. Steinmetz: In considering the tests by alternate short circuit and open circuit, we must realize one feature. In all other tests it is always necessary to make a correction for the field excitation, which is higher or lower than that for full load. We alternate over-voltage runs at open circuit, with over-current runs at short current. Thus we have two independent

variables, and we are enabled to so select the over-voltage, the over-current, and the time period that not only the total losses during each cycle are equal to the full load losses, but also the total losses in the field are identical with the full load losses. Consequently you can obtain the correct field heating as well as the correct armature heating. This test seems to me to have considerable merit, and is often the only practical test available.

In regard to the alleged complexity of switching over to change open circuit to short circuit, and vice-versa, that requires two short-circuiting switches, one across the armature and one across the rheostat in series with the field. To operate two switches is not a very complicated matter. You will not have to adjust the field or effect any other adjustments. These adjustments are made before starting the test. We thus see that the switching operations are extremely simple. But whether the test is generally applicable or not depends entirely on further investigation. There is a possibility that you cannot adjust the two independent variables at the values necessary to obtaining the correct heating by this kind of test. It may be that the excitation required in order to circulate the appropriate armature current on short circuit will give you a higher field heating than, taken in conjunction with the excitation on open circuit, corresponds to the same total heat per cycle of operations with normal load excitation. There are several limitations which have not yet been fully investigated; for a general method, this test has merits which require careful consideration.

F. D. Newbury: There was one point mentioned by Mr. Steinmetz, which was illustrated in the case of a machine we tested. In order to divide the loads between open circuit and short circuit, so that the total losses on test at any given instant would be equal to the total loss on energy load and also that the watt-hours would be equal to the watt-hours in a test under actual operation, we found that the field losses during the test were 30.65 kw. per hour. The same losses at 100 per cent power factor and full load were 19 kw., and under zero power factor, 46.5 kw., that is, during the intermittent loss the field loss was intermediate between what it would have been at 100 per cent power factor and zero. In the test we made, I added all the short circuit losses and the I^2 losses, which may account for the higher temperatures we obtained. But that brings up the point that the method requires some experience in order to determine the proper conditions so that the test results will check with actual load. That same disadvantage is present in all tests, except to a very minor degree in the zero power factor test, and in the zero power factor test it is a condition which can be corrected for with full knowledge.

H. M. Hobart: In connection with a lot of machines which I examined, it was impossible to get the field loss right, when the other two losses were right, but the field loss was not nearly so

far out as in the zero power factor test. If the field heating is perhaps 10 per cent higher than under normal conditions, it does not seem to me it is vital, you can easily correct it, whereas you cannot make a reasonable correction of what the field temperature would be in actual practise, when it has been tremendously over-excited as in the zero power factor test.

During the short circuit period the loss can be different from what it is during the open circuit period, so long as the loss in each part, in the course of a definite period of time, say one hour, is the same as in actual practice. It may be of interest, to state that this intermittent open circuit and short circuit method of testing alternators is not new but was described by Mr. Franklin Punga and myself in the *Electrical World* for April 22, 1905. I have again drawn attention to it in an article entitled "A Method for Testing the Heating of Large Alternators" in the *General Electric Review* for November 1911. In 1905 I employed the method in the testing some large three-phase generators.

Alexander Gray: It seems to be my misfortune always to get erratic results. In testing induction motors, it is very important to notice whether there is a pulley on or not. I remember particularly a small 20-h.p. motor, running at 1800 rev. per min., which was supposed to drive looms by means of four belts and two pulleys. A motor at that speed is, of course, a small dumpy machine and rather long. That machine, tested with a pulley, rose 42 deg.; tested with two pulleys, one on each side of the machine, it rose 28 deg. cent. I could guarantee that the machine if direct-connected so as to operate without pulleys would have a temperature rise of 50 deg. I want to offer the suggestion that motors should be tested, as far as possible, under conditions under which they are going to be run.

W. J. Foster: What occurred to me at first, at the mention of the pulley, is something I have seen in a great many machines, and this is a movement of the air axially, a movement caused by a mechanical connection simply, a thing even more simple than a pulley, and where the rise in temperature in the machine is due to the fact that that small influence overcomes the natural radial movement that would exist and causes a totally different flow of air, an axial movement. Undoubtedly many of you have run across this trouble. Therefore, when Mr. Gray mentioned placing the two pulleys on the machine, it seemed to me that he then had the motor in approximately the same condition it would be without any pulleys whatever. This may not have been the explanation in that particular case, but in certain cases I have known it has been the cause of high temperatures.

Alexander Gray: I want to confirm Mr. Foster's remarks about alternators. An alternator is generally put on a heat run during the night and temperatures are taken in the morning. It is often found that when the men come in at seven o'clock in the morning and open the door, the method of ventilation of the alternator is completely changed, and the temperatures also

change so that it is always advisable to take temperatures before the men come in. As to the effect of a belt, the effect might be as follows: In a long machine the stator coils stick out beyond the core for a considerable distance and the tendency is for the cooling air to strike the coils and be drawn back into the rotor again, and so become hotter and hotter. The action of the belt creates the same kind of pressure on one side of the pulley and a suction on the other, and tends to draw the hot air out.

S. S. Seyfert: I would like to make a suggestion regarding the loading of alternators. It seems possible to subject a machine to normal current and voltage conditions without incurring the difficulties encountered in the methods discussed.

I was thinking of a method similar to the so-called pump-back test on transformers. Normal voltage conditions may be obtained by running the machine at the proper speed and excitation and normal armature current conditions, by impressing across the phases, properly connected in series, a reduced voltage of *approximately normal frequency*. The armature currents would have no resultant motor or generator action. The prime mover would supply core and friction loss and the reduced voltage source would supply the armature copper loss. The increased heating developed when direct current is used on the opened delta should not occur.

In case the armature phases could not be opened so as to be properly connected, a bank of transformers, equivalent in capacity to the largest unit tested, would be required.

Edgar Knowlton: *Open Delta Method.* This test has given very erroneous results when the three-phase armature winding had a pitch differing from $\frac{2}{3}$ and the field was of the laminated cylindrical type. In several tests the temperature rise of the rotor winding was about 100 per cent, and of the armature winding about 20 per cent greater than that obtained under full load conditions. A solid cylindrical field would doubtless cause still greater temperature rises.

C. J. Fechheimer (communicated after adjournment): The zero power factor method of making heat runs on alternating-current generators is in general the most desirable one, provided the necessary equipment is available. Although this method may give slightly pessimistic results in regard to temperature, especially that of the field coils, it should be remembered that it is difficult to predict the power factor of a system. The effect of lagging currents of lightly loaded induction motors upon reducing the power factor is seldom appreciated. Even though generators be sold for 80 per cent power factor, it is well to give the customer the benefit of every doubt and test his machines at zero power factor. If desirable, we can easily determine what the rotor temperature will be, by taking this to vary as the square of the field currents.

When it is impossible to test synchronous machines at zero power factor, compromise heat runs should be made instead.

Among these is the direct-current open delta heat run which gives results closely approximating those which would obtain in regard to stator temperature when the corresponding load is applied. With this method the losses in the pole shoes with attendant rise in temperature is not nearly so serious a matter as might appear at first thought, as the magnetomotive force required for the air gap is generally so great that the ampere turns produced by the current in the delta are correspondingly small. It is often possible and desirable to use a multiple circuit winding or equivalent and cause direct current to flow so as to have currents in opposite directions in the same slot, provided the familiar two layer winding is employed. We would call attention to Mr. Sebastian Senstius' paper entitled "Heat Tests on Alternators," presented to the Institute in 1906. We believe it advisable for the Standardization Committee to consider methods of making heat runs as described by Mr. Senstius as substitutes for the more desirable zero power factor method. It is our opinion that when making such direct-current heat runs, the excitation should correspond to open circuit voltage equal to the vector sum of the impedance drop and the terminal voltage. The current could be increased to allow for eddy currents if deep conductors are used, as described by Mr. A. B. Field.* This would then give an equivalent of full load core loss and circulating currents equivalent to full load copper loss. It is generally advisable to have an open circuit heat run in addition, from which latter the field heating at any field current can be determined with considerable accuracy, as a fresh supply of air comes into the rotor (which we are assuming to be the field) and hence the temperature of the fields will not be affected by the stator temperature. The latter is undoubtedly affected by the rotor temperature, as a hot rotor causes warm air to be thrown on the stator. For two-phase machines, we could usually employ multi-circuit arrangements as described by Mr. Senstius.

When the above methods are unwieldy, we may resort to the familiar open and short circuit heat runs. We do not favor alternate open and short circuit runs of short duration. It is frequently difficult, especially on large machines, to which this method should be particularly applicable, to make such changes rapidly and unless they are made rapidly the method is hardly desirable. Furthermore, the time of application and the magnitude of the voltages and currents are subject to calculations, such calculations being based to some extent on assumptions, and hence we are liable to be misled as to the proper substitute for true full load conditions.

For a number of years we have endeavored to establish some relation between the sum of the open-circuit and short-circuit temperature rises and the corresponding load temperature

*"Eddy currents in Large Slot-Wound Conductors," TRANSACTIONS, A. I. E. E., 1905.

rise. In order for the Standardization Committee to decide what ruling to give when open- and short-circuit heat runs are made, they should have available many tests for comparison. There are to be sure many variables that come in and yet we believe it is possible to give an approximate ruling which may be applied in absence of methods for making more accurate tests.

We shall not take space to show why the load temperature rise should be slightly less than the sum of open and short circuit temperature rises. This amount to be deducted we have found to be approximately 5 deg. cent. when the sum is 40 deg. and in general is proportional to the sum. The temperature reading to be taken in short circuit and open circuit runs, as well as the load heat run, should be the maximum that any of the several thermometers record, whether they be placed on stator coils or stator iron.

In order to determine the internal voltage we add vectorially the impedance drop to the terminal voltage. The reactance can be measured with the rotor removed and normal current circulated at normal frequency in one phase of the winding; for example, if the machine be star-connected three-phase, the current should be circulated between neutral and terminal. This may not be in entire agreement with statements which others have made, but we have found, to substantiate our statement, that such methods when used for the reactance drop in determining the zero power factor curve give extremely close results.

In regard to heat runs on induction motors when the equipment for making the load tests is not available, the "Reversed Rotation Method" frequently gives accurate results but we believe this is due to a number of errors cancelling each other by chance and should generally not be relied upon. It is well known that the frequency of the currents in the rotor circuit when the motor is operated at 200 per cent slip is double the stator frequency and hence the eddy current loss may be considerable. Therefore the results are liable to be misleading. The method, in our opinion, may be used in combination with the no-load heat run, if the depth of the rotor conductor is not greater than 0.55 in. (13.97 mm.) for 25 cycles, nor more than 0.35 in. (8.89 mm.) for 60 cycle motors. Our experience indicates that erroneous results are obtained if these limits are greatly exceeded.

Usually, we prefer the reduced voltage method for determining the temperature rise due to copper loss, the induction motor being operated until the temperature ceases to rise with the impressed frequency raised above normal (*i.e.*, the motor operates with positive slip as an induction motor) and then to have the test repeated with the frequency reduced a corresponding amount below normal (so that the motor operates with a negative slip as an induction generator). In both cases the motor is operated at normal speed in order that normal ventilation be secured. The reason for operating at two frequencies is to insure an average

temperature which would be approximately the same as obtained with normal eddy current loss in the stator. The higher frequency produces too large and the lower frequency too small an eddy current loss in the stator copper. We should then allow for the temperature rise on open circuit, as Messrs. Collins and Holcombe have done, but whose equation we would modify as follows:

$$T_f = \left(T_r - T_n \frac{E_r^2}{E_n^2}\right) + \left(T_n - T_r \frac{I_n^2}{I_r^2}\right) - T_v$$

E_n = Normal voltage.
E_r = Reduced voltage.
I_n = No load amperes.
I_r = Reduced voltage amperes.
T_f = Temperature rise on stator for full load normal volts.
T_n = Temperature rise on stator for no load normal volts.
T_r = Temperature rise at reduced voltage.
T_v = Temperature rise to be deducted.

" T_v " should follow the same general ruling as applies to the alternating-current generators as indicated above.

We believe it would be well to incorporate in the Standardization Rules some means of allowing for a machine feeding back heated air upon itself. For example if the machine is placed in a testing pit the walls of the pit return to the machine the air which has been expelled, and thus cause a higher temperature rise than would be secured were the entire machine placed above the floor line. We have observed numerous tests which proved beyond doubt that if air once expelled is fed back into the machine before cooling, the temperature rise will be considerably more than if a fresh supply were fed continually.

(b) Transformers

J. M. Weed: I notice in the paper " Sources of Error in Transformer Tests " by Messrs. McConahey and Fortescue, a reference to the iron loss, as follows: " Due to the voltage drop in the primary winding, the induction in the iron will be slightly decreased in going from no-load to full load, this tending to decrease the iron loss slightly." I infer from this that the authors of this paper are thinking of the nameplate voltage as the no-load voltage, and that the voltage will be lower than the nameplate voltage at the full load condition. The voltage will be lower at the full load condition than at the no-load condition, certainly, but if we consider the nameplate voltage as the no-load voltage, this gives a reduced output to our transformers on the basis of a current rating figured on the nameplate voltage.

A similar opportunity for misunderstanding, on this same point, exists in the paper on " Losses in Transformers " by Mr. Lewis, in his recommendation No. 1, which states that the no-load losses should be measured at rated voltage minus *I r*,

where I equals rated current, and r equals resistance of primary circuit. Possibly Mr. Lewis does not mean nameplate voltage by rated voltage, but something higher, which includes the transformer drop, and will give the nameplate voltage on the secondary terminals at full load. This, however, would make the rated primary voltage dependent upon the power factor of the load, since the transformer drop depends upon the power factor. It would seem preferable to specify that the no-load loss should be measured at nameplate voltage plus $I\,r$, where r equals resistance of secondary circuit. The exact value of this correction would depend upon which winding is to be used as secondary (where the per cent $I\,r$ differs for the two windings) and upon the temperature of the transformer when the measurement is made. The correction will ordinarily be small, in any event, and my own recommendation would be to neglect it, unless for special exaggerated cases, measuring the no-load loss at the nameplate voltage.

I should like in connection with these papers (Group 3) to call attention to my discussion of the papers of Group 2, with reference to the opposition method of determining temperature rise.

C. Fortescue: The paragraph referred to by Mr. Weed brings up the question of whether the rated voltage shall be the no-load secondary voltage or the full-load secondary voltage. The paragraph referred to is true whether we consider the rated voltage as no-load or full-load—there is a voltage drop in the primary winding, and the effective induction, that is, the induction that links the secondary circuit will be slightly decreased. On the other hand, at certain spots in the iron, the leakage flux will cause the induction to be higher, than even in the case of no-load conditions. That is what I refer to in that paragraph.

In connection with Mr. Madden's paper, I want to say that I agree with the points he brings up as improvements over the methods indicated in my paper on temperature measurement. It is preferable to measure the resistance of the copper at some point during the copper or short-circuit period. The middle points are not necessarily the correct points, but if the complete period is reduced to a short length of time, then the error in taking the middle point of the short-circuit period will be negligible.

J. M. Weed: I would like to emphasize the advantages of the use of the idler in determining temperature rises of transformers, which has been fully dealt with in the papers, but I doubt if the full advantages are appreciated by many here. The idler not only supplies a satisfactory base temperature or equivalent room temperature, but also affords a more accurate method of determining the temperature rise of the transformer, which is brought out in the paper by Messrs. Johannesen and Wade. In the formula which represents the calculations which must be made from the test in order to get the temperature rise of the

windings of the transformer, nothing appears except the voltmeter readings. In the determination of rise of resistance, by the ordinary voltmeter-ammeter method, it is necessary not only to get correct results from the reading of two meters, which involves the inaccuracies of calibration as well as the inaccuracies of observation, but you must know the exact temperature of the transformer at the time you are measuring this resistance cold in order to get an accurate temperature reading. That involves many chances of error, when you consider that the temperature rise depends upon the difference between two quantities, which are large with respect to this difference, which is a consideration that is not fully appreciated. In the case of the use of the idle transformer, it is not necessary to know the temperature of the transformer when the initial resistance readings are taken, provided the transformer upon which the heat run is made is at the same temperature as the idle transformer; and, again, the same current passes through both transformers, so that it is not necessary to know the exact value of the current. It is only necessary to know the voltmeter readings. At the end of the run voltmeter readings are obtained with the same current passing through both transformers, again. In this case, in order to calculate the temperature rise, it is necessary to know the temperature of the idle transformer, but we have every opportunity to get this temperature correctly. This method, I believe reduces the unavoidable errors in determining the temperature rise to a minimum.

There is one open question, however, as to the accuracy obtained with the idle transformer, and that is as to whether it is actually affected by change of room temperature in the same manner as the loaded transformer? In the loaded transformer we have a circulation of oil due to the load itself which causes all parts of the oil to come in contact with the tank within a short period of time, whereas in the idle transformer the circulation is very sluggish. If the room is warmer than the oil, the oil coming in contact with the tank will rise slowly to the top and stand in a layer, which will gradually increase in thickness. Vice versa, if the room is cooler, the oil in contact with the tank will gradually fall and produce a cool layer in the bottom of the tank, which will gradually build up from the bottom. The average temperature of the oil may not be the average between the top oil and the bottom oil, but depends upon the distribution of temperature within the tank from top to bottom.

M. G. Lloyd (communicated after adjournment): While considering the subject of transformers I want to suggest that a definition of the term "ratio of a transformer" should be included in the Standardization Rules. Heretofore this expression has been used in a variety of senses, not only in a casual way but in printed treatises upon the subject. In looking over the literature one finds that many authors fail to define this term and others use it without any exact significance. The principal

meanings attributed to the expression are as follows, in the case of a potential transformer:

1. The ratio of the number of turns in the primary winding to the number of turns in the secondary winding.

2. The ratio of the number of secondary to the number of primary turns.

3. The ratio of the terminal voltages.

4. The ratio of terminal voltages under no-load.

5. The ratio of the induced voltages in the two windings. On account of leakage, this is not the same as the ratio of turns.

No word should be used by technical men which has not a definite meaning, and in view of the great divergence in the usage of this term it seems very desirable that a definition should be included in the rules. This definition should be one which will make the term most useful to the engineer, and unless there is some good reason for departing from the most common practice among those who have occasion to use the term most frequently in an exact sense, this practise should be standardized.

Probably the reason for the previous laxity in definiteness of meaning has been the fact that the expression " ratio " has been largely used in a qualitative sense, and naturally the ratio of turns expresses such a value. With the advent of the instrument transformer, occasion arose for the use of exact quantitative values of the ratios of terminal voltages in the potential transformer and of currents in the series transformer. The time has therefore arrived, indeed it has passed, when a quantitative definition should be standardized.

In connection with this definition there are two principal considerations. One is as to whether the ratio of the primary value to the secondary value shall be used or the ratio of the secondary to the primary. General usage as well as general opinion seems to favor using the ratio of the primary quantity to the secondary quantity, whether this be the number of turns or the electrical magnitude. I will consequently not elucidate the arguments on this point.

The second principal question to be decided is as to whether the ratio of turns or the ratio of electrical magnitudes shall be meant when the word " ratio " is used. Owing to internal resistance and to magnetic leakage the ratio of terminal voltages in a potential transformer is never quite the same as the ratio of turns. In consequence of this it is customary for the manufacturer to slightly alter one of the windings from the number necessary to give the nominal ratio of turns. The ratio of turns is not indicated on the nameplate and is usually unknown to the user. The nameplate should always, and usually does, tell the ratio of the terminal voltages under some definite condition of use, for this is the ratio of interest to the user. A similar condition exists with regard to series transformers. Here again the ratio of turns is not the value which is of interest and importance to the user, and it is not customary for the manufacturer to

state on the nameplate this ratio, but rather the ratio of primary to secondary currents under some definite condition of use.

In the case of the constant-current transformer used with primary on a constant-potential circuit, the ratios of potentials and of currents are of little interest and their values need not be known to the user.

Should the ratio represent a quantity which is fixed by the number of conductors or a quantity which varies with the conditions of use? Should it represent a quantity whose value is secreted in the archives of the manufacturer, or a quantity whose value can be determined by a simple measurement? Should it represent a quantity whose exact value is of importance to the user or a quantity which it is only useful to know approximately?

Inquiry among the men who have occasion to make use of exact quantitative values of ratio discloses a universal preference for defining the term " ratio " to mean the ratio of the primary electrical magnitude to the secondary electrical magnitude. The only point which may really seem to be at issue is as to whether this ratio should be defined as a definite constant quantity for a particular transformer, or whether it should represent a magnitude which may be changed under the conditions of use. For instance, in the case of a potential transformer shall the ratio mean the quotient of terminal voltages under particular conditions of frequency, secondary load, etc., or shall it be regarded as varying when these and other conditions of use are varied. The question is somewhat similar to that involved in making a distinction between the rating of an electrical machine and its capacity. The capacity is a quantity which varies with the conditions of use, such as room temperature, power factor, etc., but the rating may be so defined as to be a definite quantity for a particular machine independent of any temporary conditions under which it may be used. To me it seems preferable to regard ratio as a variable quantity, and I therefore suggest the following definitions:

" The ratio of a potential transformer is the ratio of the effective primary terminal voltage to the effective secondary terminal voltage."

" The ratio of a current transformer is the ratio of the effective primary current to the effective secondary current."

It is to be noted that with the above definition the regulation of a potential transformer is the change in ratio between full load and no load, expressed as a fraction of the ratio at no load.

MIDWINTER CONVENTION PAPERS

Group IV. Miscellaneous Subjects Relating to Rating

(a) OIL SWITCHES

Rating of Oil Circuit Breakers with Reference to Rupturing Capacity, by G. A. Burnham.

(b) SPARK GAP

The Sphere Spark Gap, by S. W. Farnsworth and C. Fortescue.
The Calibration of the Sphere Gap Voltmeter, by L. W. Chubb and C. Fortescue.

(c) WAVE FORM

Potential Waves of A-C. Generators, by W. J. Foster.
Wave Form Distortions and Their Effect on Electrical Apparatus, by P. M. Lincoln.
A Proposed Wave Shape Standard, by Cassius M. Davis.

(d) REGULATION

The Experimental Determination of the Regulation of Alternators, by A. B. Field.
Regulation of Definite Pole Alternators, by Soren H. Mortensen.
Generator and Prime Mover Capacities, by David B. Rushmore and E. A. Lof.

DISCUSSION ON GROUP IV PAPERS [(*a*) OIL SWITCHES, (*b*) SPARK GAP. (*c*) WAVE FORM. (*d*) REGULATION]. NEW YORK, FEBRUARY 28, 1913. (SEE PROCEEDINGS FOR FEBRUARY, 1913).

(*Subject to final revision for the Transactions.*)

Paul M. Lincoln: The paper of Mr. Burnham's on oil circuit breakers opens up an interesting subject. The question on the method of rating an oil circuit breaker is an important one, and is one upon which the Standards Committee, I believe, should take some action. I am prepared to accept most of the suggestions made in Mr. Burnham's paper. It is necessary to rate circuit breakers in various ways; one way to rate them is in regard to their current carrying capacity, and they must have such a rating. They must also have a voltage rating to indicate the maximum voltage of the circuit upon which they may be used.

These two ratings, however, do not fix the ability of a given breaker to *protect*, and it is this ability to *protect* that is of foremost interest to the operating man. It seems to me that the best method of giving such a rating is the one which is suggested in this paper, namely, the kilovolt-ampere capacity which a circuit breaker will be guaranteed to interrupt. Now, the kv-a. capacity which the breaker will interrupt successfully will depend almost entirely upon what is back of the breaker. Of course, it stands to reason that the breaker which has a small power plant back of it will not be called upon to interrupt as much as one which has a large power plant back of it. Moreover, the amount of power which the breaker is called upon to interrupt will depend not only on the size of the power plant back of it, but also on the character of the generators, and particularly on the question whether or not there are current-limiting devices placed in those generators or in other portions of the circuit, so as to limit the amount of power which the breaker is called upon to interrupt. In these days when there is such a tendency to use current-limiting devices either in generating circuits or feeder circuits, or between the sections of busbars, the method of rating breakers suggested in the paper becomes, in my opinion, the logical one. It is not logical to rate a breaker with regard to the amount of synchronous apparatus that is back of it, because a given breaker may be protected by reactance in series with it, so that the amount of power which it is called upon to interrupt is not a function of the total plant back of it, but an amount limited by the current-limiting devices. It seems to me logical therefore to rate breakers for the kv-a. capacity which the breaker will be guaranteed to interrupt.

M. G. Lloyd: I ask if there is any limitation on what happens to the breaker when it ruptures the circuit?

Paul M. Lincoln: Of course, good practise must place a limitation on that, but just what that good practise is, has not been definitely determined. It is the practise of a number of

operating companies at present to overhaul breaker contacts, after they have been called upon to interrupt short circuits, and the practise in the past has indicated that such an inspection is essential to the continuity of service. Such inspections, of course, are necessary only when the breaker is called upon to act at somewhere near its ultimate breaking capacity. In ordinary conditions, a breaker may not show the slightest signs of inconvenience or distress, but when the breaker is used at such capacities as tend to push it to the limit, there may be some throwing of oil or burning of contacts, which it is wise to investigate, before the breaker is put back into service.

M. G. Lloyd: I do not think that quite answers the point as regards the rating in the Rules. How much overhauling would be permissible for deciding that the breaker had been overrated?

Paul M. Lincoln: I do not know that the Rules could go so far as to make any definite determination of that point. I am not prepared, at least, to suggest any reading of the Rule which covers that point.

F. D. Newbury: I do not think it is a matter for the Rules to be explicit upon, and I think as long as the damage to the breaker has not been greater than can be remedied by replacement of the contact that the breaker has not been overrated.

A Member: The author has called attention to the complexity of the problem of rating circuit breakers, and the difficulty of expressing that rating is something that can be readily understood. Because of this difficulty many of the manufacturers have paid no attention whatever to the rating of the switches they buy. That may sound like a confession, if it was taken for what it is worth. Our company pays very little attention to the guarantee of the manufacturer, depending on a knowledge gained of the switches by testing and experience. The reason for that is this—the rating at present, as the author has indicated, is unsatisfactory. The amount of energy that is back of the switch is the determining factor as to what will happen to the switch when it is called upon to do extreme work, that is, opening a short circuit. It is put on a device and an automatic arrangement is put on the switch, so that it will open the short circuit when called upon. The extreme condition that it is called upon to meet is a short circuit directly back of the switch. What will happen to the switch will depend entirely on the available energy back of the switch. Just what volume of current the switch will open cannot be determined, and you cannot tell whether it will come up to specifications, as we have not a micrometer in the short circuit when it opens. We do not know what it is called upon to do and we do not know whether it meets specifications or not. It seems to me a far better rating would be the kv-a. capacity that would be ruptured, not the currents passing through the switch, but the kv-a. back of the switch, under which conditions the switch may open

sufficiently to protect the circuit—switches would be rated in certain values, instead of certain ampere values of continuous capacity, they would be rated to protect a circuit having back of it certain available instantaneous energy. Suppose they are rated for 100,000 kv-a., or any capacity that the manufacturer sees fit; that will be more good to the operating engineer than a kv-a. rating he knows he can never find out whether the switch is meeting or not.

Paul M. Lincoln: The man who installs a plant, who fixes the size of the choke coils, etc., is the man who can determine how much current a given switch will be called on to interrupt as a maximum. The manufacturer cannot determine that. If the manufacturer will say that such a switch will protect 10,000 amperes on a 100,000-volt line, and if you go beyond that you are taking chances, that is as much as the manufacturer can do. The man who installs it and applies the limiting devices is the man who can determine the maximum the switch will be called upon to rupture under the worst conditions. It seems to me that when a manufacturer has said that a given switch is good for rupturing so many kv-a. on such and such a voltage line, he has gone as far as he can. The amount of instantaneous kv-a. which the switch is called upon to rupture is not only a function of the current-limiting devices in series with it, but also a function of the time-limit which is placed on the breaker. It is well known that if you allow a breaker to stay in for several seconds after the short circuit has come, so that the instantaneous rush of current is over, and the generators have settled down to somewhere near their normal condition, that the stress on the breaker will be less severe than if they are called upon to rupture instantly.

A Member: Apparently I did not make myself clear, because my position is exactly the same as Mr. Lincoln's. We both agree absolutely. One point of my suggestion is this—that if it was stated in terms of the available energy back of it, the same thing as stating the capacity, you call the attention of the engineer to the fact that he must figure it from that side, and not figure on what is going to happen on the other side of the switch, the apparatus it protects. At the present time the rating leads the mind of the average engineer to the amount of energy that is behind the switch rather than the energy that can be pumped into it, so that we are absolutely in agreement.

Ford W. Harris (by letter): The suggestion to rate breakers by the maximum current they can safely open is not a new one, being one of those more or less obvious thoughts that occur to a considerable number of people at different times. It has to my certain knowledge been several times suggested to at least one manufacturer and on every such occasion has been finally rejected as undesirable.

In the first place it involves complications that are not at first sight evident. For example, the influence of phase relation

of the voltage and current at the instant of rupture is very marked in limiting the value of this current. If the voltage wave at the instant the current reverses is near its maximum this current is much more likely to reverse than if the voltage wave is at a low value. It would probably not be sufficient to give a single maximum value but in addition it would be necessary to state exactly how this value would be modified by the characteristics of the circuit as to inductance and capacity.

Then this safe maximum current would represent the current that would produce a failure of the breaker divided by a factor of safety. We have however no accurate measure of the failure point. At a certain current the breaker will start to throw oil and as the severity of the short circuit is increased it will throw oil, burn contacts, and produce other mechanical distortions in a greater degree. At just what point shall we apply our factor of safety? If this rating is to be a definite one, some agreement on this point will be necessary.

In the same way it would be necessary to come to some agreement as to what the factors of safety should be and how they should be modified by enclosure which prevents the breakers enclosed from being regarded as so much of a life and fire hazard.

Even if the rating were adopted I am not at all sure that it would be of any considerable engineering value, due to the difficulty of determining in advance just what current to expect at certain points and in general the impossibility of waiting until tests can be made before specifying the breakers. While there are in this country certain men who can figure what this current will be and while there exist data that could make this calculation feasible to the average engineer these data have been obtained at a very considerable expense and it is very doubtful if those who have them would care to make them public.

Considered commercially, I cannot see where this rating would be of any very considerable value. The average purchaser would rather have a blanket guarantee that the breakers he is purchasing will take care of conditions in the applications that he can define to the manufacturer than to have a partial guarantee that the breakers will open a certain current. Indeed it is very doubtful if the purchaser would be willing to dispense with the broader guarantee even if the current were defined.

In other words it seems to me that this matter of circuit breaker ratings is a much more complicated matter than has evidently been assumed and that the rating proposed is not likely to be of any very considerable value either to the purchaser or to the manufacturer.

Chester Lichtenberg (by letter): The rating of an oil circuit breaker, unlike that of most other electrical apparatus, must be given in terms both of the normal and abnormal circuit conditions under which it is intended to operate. Its complete rating requires, therefore, an enumeration of the following properties:

1. Continuous current-carrying capacity.

2. Maximum circuit pressure capacity.
3. Maximum energy-dissipating capacity.

The continuous current-carrying capacity of an oil circuit breaker is the maximum current at any given frequency which its parts will carry continuously without exceeding a specified temperature rise. This will depend primarily on the design of the device and the materials used in constructing it, and also upon the temperature and configuration of the leads connected to its terminals and the quality of this connection. The latter points are very important and in making tests of oil circuit breakers, great care must be exercised to have the temperature of the leads not in excess of that of the oil circuit breaker terminals. In general, the maximum temperature of any part of an oil circuit breaker should not exceed 35 deg. cent. above an average room temperature of 25 deg. cent., but in no case, should the maximum temperature of the oil exceed 75 deg. cent.

The maximum circuit pressure capacity, commonly known as rated voltage of an oil circuit breaker, is the maximum equivalent pressure of the circuit to which it may be safely connected. This rating depends on the design of the device, the pressure rises which may occur on the circuit in which it is connected, and the desired factor of safety. On most circuits operating at 45,000 volts and below, it is admissible to give the pressure rating of the oil circuit breaker in terms of the circuit pressure. Above this point, however, and in some special cases below it, it has been found advisable to follow the practice adopted by insulator manufacturers and give the pressure rating of the oil circuit breaker in terms of the maximum pressure it will withstand for a short interval of time such as 30 or 60 seconds and the pressure under which it can operate continuously. The ratio between these two ratings varies from 1.5 to 10, depending on the circuit conditions and the degree of safety specified.

The maximum energy dissipating capacity, generally known as the rupturing capacity, of an oil circuit breaker, is the maximum amount of energy which the device can dissipate when interrupting a circuit of given voltage and frequency. This factor of the rating is by far the most difficult to determine and fix as it depends on a large number of independent variables of design and circuit conditions. It can only be determined experimentally with considerable difficulty and within wide limits which require exact definition.

It is, therefore, suggested that the Standards Committee consider a method of rating oil circuit breakers which will include the following:

1. A current rating based on temperature rise.
2. A pressure rating based on ordinary circuit pressure rises together with a reasonable factor of safety.
3. An energy dissipating rating based on the maximum current which the device can safely interrupt on a circuit of given pressure and frequency at the least favorable power factor without showing any external signs of distress.

It is also suggested that:

1. The maximum temperature rise on any part of an oil circuit breaker should be limited to 35 deg. cent. above an average room temperature of 25 deg. cent., but in no case should any maximum temperature exceed 75 deg. cent.

2. Oil circuit breakers for use on circuits between 2500 and 45,000 volts shall be able to withstand a high pressure test between live parts and ground of three times rated pressure for 30 seconds.

3. Oil circuit breakers for use on circuits exceeding 45,000 volts shall be able to withstand a high pressure test between live parts and ground of $2\frac{1}{2}$ times rated pressure for 30 seconds.

4. The safe rupturing capacity of an oil circuit breaker shall be the maximum equivalent current which the device can interrupt at rated pressure and frequency at the least favorable power factor without showing signs of distress, and shall be given in amperes at rated pressure and frequency.

5. The maximum rupturing capacity of an oil circuit breaker shall be the maximum equivalent current in amperes which the device can interrupt without being destroyed and shall be given in amperes at rated pressure and frequency.

F. W. Peek, Jr.: In the discussion of the interesting paper of Messrs. Chubb and Fortescue on their development of the sphere gap voltmeter it may be of interest to state our experience, and add data which we have obtained in this work.

The needle gap has long been a useful means of approximating high voltages; with the present extra high voltages, however, we have about outgrown it. Although it is possible to measure high voltages with a fair degree of accuracy with the needle gap, too much skill is required, and too many variables must be considered, especially at extra high voltages. The voltmeter coil offers a reliable means of high-voltage measurement, but a gap method is often desirable because the gap measures the maximum point of the wave and this is what determines the breakdown of insulation. With a gap method it is thus not necessary to take oscillograms, except to know that the wave fairly approximates the sine: that is, is a good commercial wave. The sphere gap used within the limits described below seems the best solution of the practical problem. It is free from the eccentricities of the needle gap, requires less skill in manipulation, the space factor is small and, furthermore, the curve can be readily calculated within small percentage error. There is one variable that must affect all gap measurements—air density. Over the ordinary range of temperature and variation of barometer *at or near sea level* correction may be made by multiplying by δ, where

$$\delta = \frac{3.92\, b}{273+t}$$

For high altitudes, where the range of δ is large, the correction

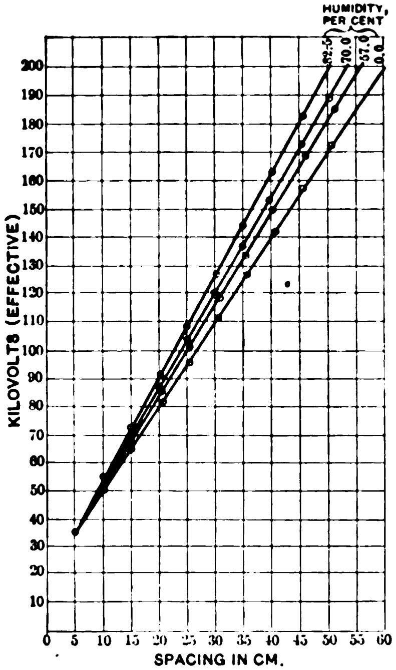

FIG. 1—NEEDLE-GAP CURVES FOR DIFFERENT RELATIVE HUMIDITIES.

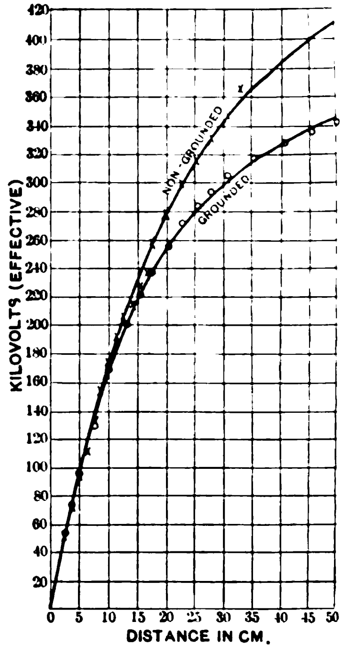

FIG. 3—SPARK-OVER CURVE, 25-CM. (DIAMETER) SPHERES.

Drawn curve, calculated; points, measured values.

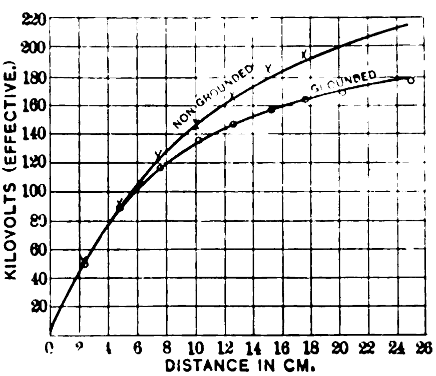

FIG. 2—SPARK-OVER CURVES, 12.5-CM. (DIAMETER) SPHERES.

Drawn curves, calculated; points, measured values.

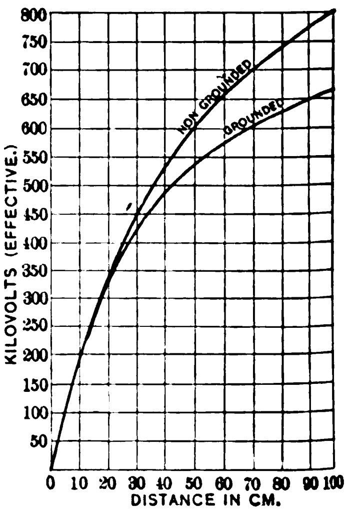

FIG. 4—SPARK-OVER CURVES (CALCULATED) 50-CM. (DIAMETER) SPHERES

is slightly different and will be given later. The following curves are for 25 deg. cent. and 76 cm. barometer.

The Needle Gap. The needle gap is generally unreliable, due to the broken-down air which surrounds the gap long before the spark passes, and to the large space factor which makes it necessary to remove surrounding objects to a great distance for consistent results. The broken-down air causes discrepancies by heating the gap, and there is also a very great variation with varying humidity. The effect of humidity is shown in Fig. 1, where it can be seen that a higher voltage is required to spark over a given gap when the humidity is high than when it is low. The curve thus varies from day to day as much as 20 per cent.

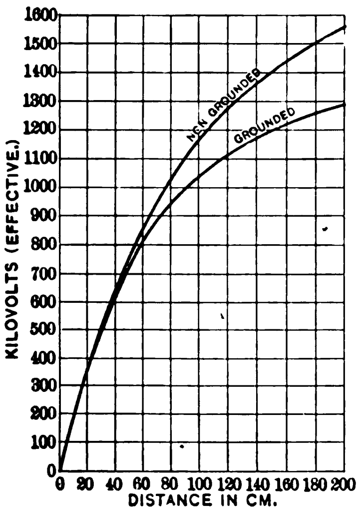

FIG. 5—SPARK-OVER CURVE (CALCULATED) 100-CM. (DIAMETER) SPHERES

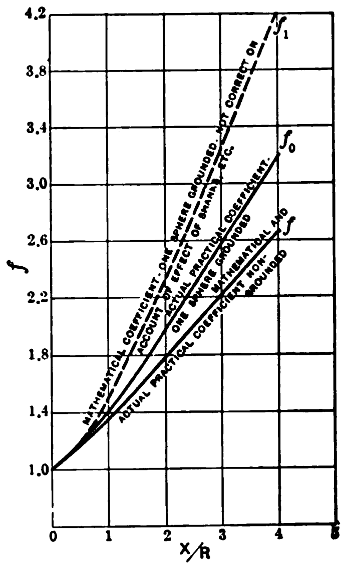

FIG. 6

It is probable that the corona streamers in humid air cause a fog, as it were, agglomerating the water particles and these, in effect, increasing the size of the electrode. There is also considerable variation with the sharpness of the needle, and probable variation due to local resonance set up by the streamers. Needles must be changed after each spark-over.

The Sphere Gap. The voltage required to spark over a given gap between spheres increases with the diameter of the sphere. If a sphere is chosen so that the spacing for the required voltage is never greater than two times the sphere radius, the first evidence of stress is complete spark-over, corona can never form, and all of the undesirable effects and variables due to the broken-down air are eliminated. Humidity has no measurable

effect. The space factor is small—for instance, at 200 kilovolts, the gap between needle points is from 50 to 60 cm., for 25-cm. diameter spheres it is only 13 cm. (It is desirable to have the spheres or needles at least twice the gap distance from surrounding objects.) It is not necessary to polish the spheres after each spark-over. Several thousand measurements may be made without repolishing. Discrepancies in sphere-gap tests made years ago, 1895, were probably not due to condition of sphere surface, but to changes in wave-shape and difficulty in measuring voltage. The curves may be accurately calculated. With 12.5-, 25-, 50- and 100-cm. spheres, a range of voltage from 20,000 to 1,500,000 may be covered. It must be noted that the curves are different when one

TABLE I—SPHERE GAP SPARK-OVER VOLTAGES*
12.5 CM. SPHERES

Spacing		Kilovolts effective	
Cm.	In.	Non-Grounded	Grounded
0.25	0.098	6.5	6.5
0.50	0.197	12	12
1	0.394	22	22
1.5	0.591	31.5	31.5
2	0.787	41	41
3	1.181	59	59
4	1.575	76	75
5	1.969	91	89
6	2.362	105	102
7	2.756	118	112
8	3.150	130	120
9	3.543	141	128
10	3.937	151	135
12	4.72	167	147
15	5.91	188	160
17.5	6.88	201	168
20	7.87	213	174

sphere is grounded and when both spheres are insulated. Fig. 2 gives grounded and non-grounded curves for the 12.5-cm. sphere, Fig. 3 gives curves for the 25-cm. sphere, Fig. 4 gives curves for the 50-cm. sphere, and Fig. 5 gives curves for the 100-cm. sphere. In all of these the drawn curve is calculated, while the crosses mark the measured values. The calculated curves were drawn long before measurements were made on the larger spheres, from laws derived from a series of tests on spheres ranging from 0.32 to 5.0 cm. in diameter. No measurements have been made on the 100-cm. sphere, but the calculated curve, Fig. 5, should be correct within a small percentage. Measured values are given in Tables I, II and III. Practical range for different diameters is given in Table IV.

TABLE II—SPHERE GAP SPARK-OVER VOLTAGES*
25-CM SPHERES

Spacing		Kilovolts effective	
Cm.	In.	Non-Grounded	Grounded
0.5	0.197	11	11
1	0.394	22	22
1.5	0.591	32	32
2	0.787	42	42
2.5	0.983	52	52
3	1.181	61	61
4	1.575	78	78
5	1.969	96	94
6	2.362	112	110
7.5	2.953	135	132
10	3.937	171	166
12.5	4.92	203	196
15	5.91	230	220
17.5	6.88	255	238
20	7.87	278	254
22.5	8.85	297	268
25	9.83	314	280
30	11.81	339	300
40	15.75	385	325

TABLE III—SPHERE GAP SPARK-OVER VOLTAGES*
50-CM. SPHERES

Spacing		Kilovolts effective
Cm.	In.	Grounded value
2	0.787	40
4	1.575	76
6	2.362	112
8	3.150	145
10	3.937	185
12	4.72	220
14	5.50	250
16	6.28	275
18	7.07	300
20	7.87	320
22	8.65	345

*At 25 deg. cent. and 76 cm. barometer.
Effective sine wave voltage.

TABLE IV

Diameter cm.	Grounded Effective kv.† Range	Non-grounded Effective kv.† Range
12.5	50–170	50–200
25	50–320	50–375
50	50–600	50–725
1000	50–1200	50–1400

† Sea level—spacing not exceeding 3R.

A curve on the 12.5-cm. sphere was made up to 25,000 volts at 1000 cycles and coincided with the 60-cycle curve. At 50,000 cycles similar curves were made on spheres and needles. The sphere gap curve for this frequency was somewhat lower than the 60-cycle curve, while the needle gap curve was very much lower. If a needle gap is set so as to just spark-over when a steep wave-front or high-frequency voltage of constant value is applied, and a sphere gap is similarly set, and these two gaps are then placed in parallel, and the same impulse voltage applied, apparent discrepancy results. Spark-over will take place across one gap, and not the other, even when the spacing on the non-sparking gap is decreased. This will be noticed in all cases where electrodes of different shape are employed in multiple. The reason, apparently, is that energy is necessary to start rupture in the dielectric, the amount of energy varying with the shape of the electrode. This introduces a very small time element which differs for different gaps. The effect, however, is rarely

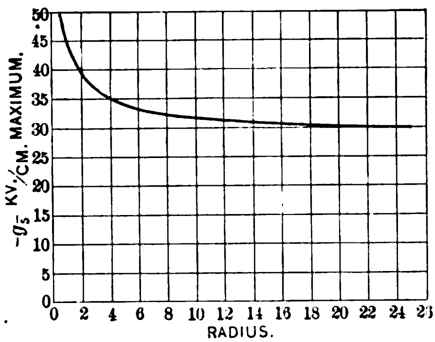

FIG. 7

noticed in commercial voltage waves, as any variation in the wave shape, in commercial waves, is not sufficiently abrupt, or is slow compared to the time lag. Naturally as the time lag is very short, it can not be measured by the oscillograph or any other instrument with mechanically moving parts. It has been studied by comparing spark distances of different electrodes in parallel. The effect is important in lightning arrester gaps where the protecting gap should have a smaller time lag than the protected apparatus—that is, the protecting gap must discharge before the apparatus breaks down.

In making arc-over tests, as for instance, on insulators, the effective transformer ratio should first be calibrated by sphere gaps. The arc-over test should then be made with sphere gaps out of the circuit and voltage determined by the calibrated ratio curve. Care should be taken that the same generator and the same method of voltage control be used in the arc-over test as in the calibration test.

Method of Measurement. Up to 200,000 volts, measurement was made by a voltmeter coil giving a great degree of accuracy. Check was made on this by step-down transformer, by ratio and by corona starting point, results from which were all in agreement. Above 200,000 volts, step-down transformer and ratio were used. The voltage ratio was very close to turn ratio. A good wave, very nearly sinusoidal, was used, and oscillograms were taken for correction in low side transformer, in voltmeter coil and in step-down transformer. The waves on high and low side were practically the same.

Water tube resistances were used in series with the gap, limiting the arc current to from 0.25 to 1.00 ampere. The potentiometer method[1] of voltage control was used.

Calculation of Curves. The voltage gradient on the air is greatest at the sphere surface. This stress or gradient derived mathematically is expressed[2]

$$g = \frac{e}{x} f \qquad \text{(kv/cm.)}$$

where e is the applied voltage, and x is the distance between sphere surfaces. e/x is the average gradient, and f is a function of $\frac{x}{R}$, where R is the radius of the sphere in cm. The f is different in the two cases when one sphere is grounded, and when both spheres are insulated. The values of f for the two cases are given in Fig. 6. We have found experimentally that g_s, the surface gradient at spark-over, as in the case of g_v for corona on wires (see Fig. 7), increases with decreasing radius. It may be expressed[3]

$$g_s = g_0 \left(1 + \frac{a}{\sqrt{R}}\right)$$

g_s for a given size of sphere is constant for the practical range of spacing used in measuring, that is, when x is not less than about $0.5 \sqrt{R}$, not greater than $3 R$. When x is less than $0.5 \sqrt{R}$, g_s increases very rapidly because the spacing is then less than the "rupturing energy distance."[4] At very small spacings gradients as high as 200 kv. per cm. are required for rupture. The "rupturing energy" has been calculated for wires.[4]

The increased value of g_s when x is large seems to be only apparent and due to the shank, surrounding objects, etc., better distributing the flux or lessening the flux density. When

1. See *The Law of Corona and the Dielectric Strength of Air*, by F. W. Peek, Jr., TRANSACTIONS A. I. E. E., 1911, XXX, III, p. 1889.

2. Mathematical values of f have been derived by Russel, *Philosophical Magazine*, vol. XI, 1906.

3. The constants are approximately $g_0 = 27.2$ $\quad a = 0.54$.

4. See *The Law of Corona and Dielectric Strength of Air-II*, PROCEEDINGS A. I. E. E., June, 1912.

both spheres are insulated this effect is small and is inappreciable for large spheres where the mathematical f may be used. When one sphere is grounded, however, this apparent increase of gradient is very great if the mathematical f_1, which does not take account of surrounding objects, is used. The f values given in Fig. 6 are for the ***non-grounded case.*** They are the ***mathematical values*** and, within the limits prescribed, ***give a practically constant graded*** g_s. The dotted line, Fig. 6, is the mathematical curve for the grounded case. This does not hold, due to the effect of shanks, etc., which it does not consider, and the actual curve is f_0. This was derived experimentally, assuming g_s constant.

For a given value of $\frac{x}{R}$, f_0 is constant, independent of the size of the sphere (from tests on spheres from 0.32 to 25 cm.). Where x is greater than $2\ R$ (practically $3\ R$) the expressions do not hold, because corona then forms before spark-over.

We have then

$$g = \frac{e}{x} f \text{ (mathematical)} \quad \text{(kv./cm.)}$$

$$g_s = g_0 \left(1 + \frac{a}{\sqrt{R}}\right) \quad \text{(experimental) (kv./cm.)}$$

Therefore

$$e_s = g_0 \left(1 + \frac{a}{\sqrt{R}}\right) \frac{X}{f} \quad \text{(kilovolts max.)}$$

or

$$e_s = g_s \frac{X}{f}$$

As an example of its use—

What is the spark-over voltage for 25-cm. spheres (one grounded) 20 cm. apart?

$$R = \frac{25}{2} = 12.5$$

$$x = 20$$

$$\frac{x}{R} = \frac{20}{12.5} = 1.60$$

$$g_s = g_0 \left(1 + \frac{a}{\sqrt{R}}\right) = 31.2 \text{ kv./ cm. max.}$$

(See Fig. 7)

$$f_0 = 1.74 \text{ (from Fig. 6).}$$

$$e = g_s \frac{x}{f_0} = 362 \text{ kv. (max.)}$$

$$e = \frac{362}{1.41} = 256 \text{ kv. (effective)}$$

For small spheres the range of the constant part of the g_s curve is very small, as the effect of shanks extends over a greater range. Hence, in practise, the above expression is especially applicable to spheres 10 cm. in diameter and above.

In order that the sphere gap may be used at various altitudes, and corrections made, curves must be taken at various air densities. The full correction will be made as in the case of parallel wires:

$$g_s = \delta g_0 \left(1 + \frac{a}{\phi(\delta)\sqrt{R}}\right)$$

This is being investigated. The constants of these equations will be given when the data are more fully worked up.

C. E. Skinner: Those of us who have had to deal with the old needle gap in the years gone by know all the trials and tribulations through which we have had to go in trying to get accurate measurements of voltages higher than 50,000. In listening to the discussion of the various papers that have been offered here in the last three days, we have all noted the differences and the difficulties which have come up and the problems which have been put up to the Sub-committee on Revision of Standards. Here is a case where it would appear that the work done could be accepted without change, and probably with little or no criticism. The use of the sphere gap for something like two years in a practical way has shown its adaptability and its convenience, its acuracy for all kinds of conditions, and the calibration, by different observers and by different methods is very close. I think the Institute and the Standards Committee are to be congratulated on one set of papers, which ought not to require much further testing or question.

I might incidentally mention that one of the greatest difficulties encountered in connection with the sphere gap is the manufacture of the spheres themselves, as the manufacture of accurate spheres of the sizes which are required for these gaps is no easy matter.

J. A. Sandford, Jr.: There is one decided advantage, I think, in the use of the sphere gap as compared with the needle gap, which was not mentioned either by the authors of the paper or by Mr. Peek, to any one who has a large number of measurements to make by the use of the spark gap. I refer to being able to take measurements with the voltage on the test piece, and moving the gap from a wide separation up to the point where the spark jumps. If I am not mistaken, the sphere gap will give accurate readings under those conditions, and on this point I would like to have Mr. Farnsworth and Mr. Fortescue corroborate what I say. I think we will at once realize what this means. It simply means we need take only one reading in each case to establish what the voltage is at that particular instant; this in contrast to the large number of readings necessary to determine the test

voltage when using the method described by Mr. Peek in the A. I. E. E. TRANSACTIONS for 1912, page 908. Of course, natually, as in all other work, it requires several readings in order to get a fair average, but with the needle point spark gap I think it is quite well known if the voltage is applied to the test piece with a wide separation of the points, and then, carefully as you may bring the points together, it will be found that the readings will vary greatly, and at least there will be some difficulty in getting accurate results, and I feel that this one thing alone has probably saved me at least 75 or 80 per cent of the time I have to use in tests of this kind.

Comfort A. Adams: May I ask those who have used this method what percentage of accuracy it is reasonable to expect in the use of the sphere gaps by men such as are ordinarily called upon to make routine tests of this sort in manufacturing establishments?

L. W. Chubb: In answer to Prof. Adams's question in regard to the accuracy reasonable to expect with the sphere gap, I will say that we believe that variations depend entirely upon the steadiness of the circuit, transformer, and switching apparatus. We believe that the true accuracy of the gap is within a very small part of one per cent. If a spark passes, the potential difference between spheres has reached a very definite voltage and after the spark has passed any further rise of potential between the spheres is practically prevented.

On a steady circuit below 100 kv-a. if the gap is opened beyond the breakdown and slowly closed, the results have been found to check within less than 0.05 cm. At higher voltage, when little jumps of corona in the high-tension circuit are apt to produce surging, or on unsteady circuits, repeated determinations may vary considerably but such variation is not chargeable to the sphere gap.

If you will refer to the curves in the paper you can see with what precision the points fall upon the (envelope) curve drawn.

S. W. Farnsworth: In answer to Mr. Sanford's question we can say that the method of measuring a given voltage by moving the spheres together until breakdown occurs is a reliable one.

The paper which we presented, purposely avoids entering into a theoretical discussion on the breakdown voltage between two equal spheres, for this has been well covered by others. We do not feel that we are the first who have considered using spheres for a spark gap, but, so far as we know, we are the first in this country who have used large spheres for the large voltages which we are daily using, and the results which we have obtained have been so satisfactory that we feel the manufacturers will be benefited by having spheres adopted as a standard in place of the present needle gap standard. It may be well to quote from an article by Mr. J. Lustgarten on "High-Tension Porcelain Line Insulators," which appeared in the July,

1912, number of the *Journal of the Institution of Electrical Engineers:*

"With regard to the spark gap, there is a tendency to measure voltage by the needle-point spark-gap standardized by the American Institute of Electrical Engineers. Those who have worked with the gap specified know that it is difficult to check the American values and even to repeat their own results on successive days. One reason for this lies in the effects on the brush discharge of humidity, pressure and temperature, position of the needles with respect to the supports and neighboring objects and the local conditions of the circuit. The brush discharge in the case of needle-points always precedes the spark (excepting at very small distances). A screening by metallic discs at the back of the needles will not prevent humidity, pressure and temperature destroying the standard gap. The author uses spheres, the diameters being chosen so that no brush discharge, or rather, no glow, will be observed at the sparking voltage. Thus all sparking voltages are below the uncertain kink stage in spark-distance curves, the kink being due to the formation of the brush discharge. The effect of humidity is eliminated. The effect of temperature can be corrected, the spark potential varying inversely as the absolute temperature. Variations in atmospheric pressure affect the spark potential less before the brush stage than after. Weicker gives the corrections for spark potentials for a 10-mm. variation in pressure from 735 mm., as 1.36 per cent. Up to 70 kv. (r.m.s. values) 2-cm. diameter spheres are suitable, to 125 kv. 5 cm., and to 200 kv. 10 cm."

This article gives the opinion which an English experimenter holds of our present needle-gap and the proposed sphere gap.

Messrs. Chubb and Fortescue in their calibration of the proposed gaps, have not dealt with the effects of humidity, temperature and pressure, and while it may be advisable to investigate with respect to these, it hardly seems necessary in view of the great quantity of evidence already available.

The article by Weicher which was referred to in the quotation above, is the most complete investigation of the general subject of sparking voltages that has come to our attention. It is to be found in the "Mitteilungen ueber Forschungsarbeiten auf dem Gebiete des Ingenieurwesens," Berlin, 1911, No. 100, pp. 1-48.

His investigations bear out the results obtained by others, and it can be stated that for the sphere spark-gap used over a separation not greater than the diameter of the spheres that the influence of the factors of humidity, temperature, pressure, frequency and electrode capacity on the sparking voltage is as follows:

Humidity—No effect.

Temperature—The sparking voltage is inversely proportional to the absolute temperature.

Pressure—The sparking voltage is directly proportional to barometric pressure.

Frequency—Within the range of commercial frequencies—namely, 20 to 75 cycles, frequency has no effect on the sparking voltage.

Electrode capacity—So far as we know, Weicker is the only one who has investigated the effect of electrode capacity, particularly, and he states that it has no influence on the sparking voltage.

Comfort A. Adams: May I ask again in regard to the frequency? It is stated that it was between 60 and 70 cycles. Was the investigation carried beyond this range, and is there any difference between a flat-topped e.m.f. wave and a very peaked e.m.f. wave?

L. W. Chubb: The frequency range for our work was from 25 to 70 cycles. The results were independent of frequency as far as we could judge. The results expressed in terms of maximum voltage were also found to be independent of wave-shape through a rather wide range of voltage distortion. I believe that it can be shown both experimentally and theoretically that the break is dependent upon only the maximum potential between spheres and independent of frequency even as high as one million cycles provided the spheres are working below the corona point.

Oscillograph tests were made with some very peaked waves at 100 kv. and directly on the high voltage circuit. The records showed that the break came at the peak of the wave as closely as could be measured.

Voltage across the gap was recorded on the film. No change could be found in the cycles preceding the break. The voltage dropped quickly to zero when the break came, and by comparison with the previous cycle it was evident that this drop started at the maximum point. Such is not the case when the needle gap or other electrodes are used above the corona point and in series with resistance. There is quite a disturbance due to the streamers before the break.

I agree with Mr. Peek that it requires a certain amount of time for the spark to take place, but I believe that with the spheres it will take place if the voltage reaches the critical point and drops at a rate corresponding to the peak of a million cycle wave. Certainly the unstable point has been reached and the electrostatic charge of the spheres can flow through the spark just as quickly as it can flow back into the circuit. Such would not be the case with the progressive discharge of the needle gap as the electrostatic charge would be expended in ionizing the air near the electrodes.

Percy H. Thomas: It seems to me with this sphere gap we have made quite a distinct advance in the measurement of alternating current voltages I want to suggest two thoughts; the first is this: In view of the relatively high capacity of the

gap itself, on account of the spherical form of terminal, compared to the needle-point terminals, a certain material charging current will flow to the terminals. If series resistance is used, as is usually the case with the gap, we cannot rely on the gap to take account of disturbances of all frequencies, because the resistance will cause a drop on high frequency on account of the charging current of the spheres. For waves of 60 cycles, or 120 or 133 cycles, undoubtedly resistances can be introduced so small as not at all to interfere with the accuracy of the method, but with frequencies of 10,000 cycles or 100,000 cycles, I should say it would be necessary to be very careful to see that no resistance in series with the gap terminals was vitiating the results.

One result of this condition is to cut out from the gap the effect of any accidental oscillations of very high frequency that may be superimposed on the alternating voltage, and if in testing a transformer, some little spark from the terminal somewhere sets up an oscillation, with spark-gap needle points, that oscillation will make the needle-points break down. With the sphere gap, using a large series resistance, I should expect the gap would not show these little superimposed high-frequency oscillations.

The second thought I wish to offer is that the sphere gaps can not always be safely used, except without series resistances, for determining the maximum voltage on high frequency experiments, and even without series resistance, it could be used only where its capacity is small in regard to the capacity of the apparatus which is being tested.

I want to take this opportunity to ask Mr. Peek some questions, with regard to the actual time required for the breakdown of an air-gap. Suppose we apply instantly, a voltage to an air-gap four times as great as the voltage necessary to break it down, I would like to know if Mr. Peek can tell us how long it will take for the first flow of current to occur across the gap, assuming there is no inductance in the system other than the discharge gap?

I would like also to have some statement of the experimental evidence, on which the conclusion is based that there is a time-lag in the breakdown of an air gap.

This is a very important and a very interesting matter, and it is a thing which keeps coming up—this matter of the lag of the spark gap at breakdown, and it is put forward as the explanation of a great many of our high frequency phenomenon. Personally I am open-minded on the subject. I have not been convinced by any of the experiments I have so far seen or heard reported of the existence of this lag as a material factor, and yet I am not sure that there is not such a thing. Are we not justified in concluding that, if there is a lag in the break down of an air-gap, it is only material for extremely high frequencies, less than a millionth of a second. Take, for example, the famous surges of Hertz, with Maxwellian electromagnetic waves. Hertz

explored with a small circle of wire having a small air-gap in it, and his discharge apparatus, if I am not mistaken was small and of very high frequency. He had sparks across a small air-gap. If his air-gap must necessarily have considerable time to break down, it could not break down on frequencies the alternations of which are less than the time of break down, because the mechanical force on the electron will alter in direction with the alteration of the applied e.m.f. The air-gap was able to break down on the frequencies Hertz used, which were very, very high, and if this logic is sound, the range of spark lag must be much less than a million cycles per second.

Paul M. Lincoln: The gaps which Hertz used in his experiments were extremely minute. I do not remember just what they were, but they were of the order of a few thousandths of an inch at the most, as I recall. As I see it, this breakdown of the air is a progressive action; particles of the air next to the terminals become ionized and they, by collision, ionize other particles. That means, if I am correct that the time of breakdown of the air-gap is a function of its length, so that the air-gap which Hertz used would break down many, many times quicker than the air-gaps described for instance in the paper read by Mr. Thomas in December.

C. Fortescue: In the first place, the condition of breakdown through the insulator is entirely different from the condition of breakdown between two large spheres that are separated a distance less than their diameter. We might compare the operation of the small sphere or an insulator and the operation of the two large spheres which are separated less than their diameter, to the operation of an ordinary trigger of a gun and the operation of a hair trigger; the sphere gap being represented by the hair trigger. The very instant that the intensity at the surface of the sphere reaches a certain point the break down occurs. No energy is required to complete the rupture outside of that already stored in the electric field between the spheres. The distance the spark has to travel is a minimum, and the action is like that of a hair trigger.

Mr. Thomas makes mention of the lagging of the spark. It may be safely said that the sphere gap is, in that respect, infinitely superior to any other method of measuring the maximum voltage that has yet been suggested. In the case of the needle spark-gap, in order to produce breakdown, all the air surrounding the points has to be ionized. This means that there is an energy component in the e.m.f. between the points and the edge of the corona which not only produces a lag of the actual e.m.f. at the point of breakdown but also causes a change in the wave form of the e.m.f. between the edges of the corona from that between the points. Thus in the needle spark-gap there is no doubt quite an appreciable lag for very high frequencies, but with the sphere spark-gaps as we have recommended them, I think that the lag, if such does exist, is extremely small.

As far as the small spheres are concerned, they produce just about the same action as needle-gaps. Wherever there is corona at breakdown there is bound to be a lag, because there must be enough energy in the oscillation to produce the corona before breakdown can take place, and where the energy has to be stored in the field there must necessarily be a time lag of the e.m.f. at the points of rupture. This is entirely eliminated where large spheres are used because then we have a condition of breakdown without corona.

M. W. Franklin: I do not happen to call to mind now any definite researches bearing on the matter of the time required for the formation of a spark, and therefore I can only speak from a sort of integrated activity in reading and following such papers for the last ten or fifteen years. As I remember it, it is a definite, experimental fact that there is a time element in the formation of a spark, even in the case of a spark between two spheres, and that time must, I think, be reckoned in millionths of a second at the utmost.

Furthermore, in regard to the suggestion that Mr. Thomas made, it does not at all follow that it requires even a millionth of a second for a spark to break down, that that spark gap cannot break down at ten million cycles. If you only consider that there may be a dozen cycles of e.m.f., each one causing a to and fro surging of the two electrons which happen to lie in the body, and that to and fro surging creates more electrons, until there is a cumulative effect, you can see that such a thing is possible from a half dozen cycles of enormously high frequency, and I do not think it possible to argue, because the spark gap breaks down at 10,000,000 cycles, therefore the time lag must be less than a ten-millionth of a second. I am quite firmly of this opinion, not from a theoretical point of view, but merely as a result of having read nearly everything that has been published on the subject of discharge through gases during the last fifteen years, and I am sure Mr. Peek and those who have been working on the subject are justified in thinking of a time-lag as existing. I am quite sure, also, that that time must be extremely small, in the neighborhood, no doubt, of millionths of a second, but I am also quite sure that the criterion suggested by Mr. Thomas would not be a proper criterion, even for forming an estimate of the extent of that time lag.

Charles P. Steinmetz: A few years ago Mr. Hayden and myself made some rather extensive investigations on the disruptive strength of air between spheres and needles, using impulses. The results of these investigations show a time lag, which was startlingly large, and measured not by microseconds, but by milliseconds, under the conditions of the experiments. Our conclusions however, were that, (at least under our test conditions), it was not so much a time lag, as an energy lag; that the breakdown is not a question of time but a question of energy and that the time lag may vary with the rate of energy supplied, and be variable at the disruptive point.

That puts an entirely different phase on the question of high frequency. You may have millions of cycles and still no appreciable time lag, because as each successive half wave subsides, the next half wave continues. So it is quite likely that the phenomenon which we call the time lag, and which has been more or less elusively indicated in very numerous tests and observations is merely the result of the obvious fact that it requires energy to break down air, and that energy must be supplied, and that the break down, therefore, must be compared to the amount of time necessary to bring that energy to the point of disruption.

That leads us, however, to some interesting conclusions. At the spark-gap between needle-points, the corona or brush discharge which appears is very extensive and affects an enormous volume of air. The amount of energy which is absorbed by the brush discharge is enormously large, very many times greater than the energy of electrostatic charge of large spheres, and experience seems to show that the time lag in discharging at very high voltages between needle points is very many times greater, and that the energy of the current flowing into the needle points before the discharge, is also very much greater, than the energy or current absorbed by large spheres, and that also explains the superiority of spheres, provided they are used at such voltages as do not occasion corona. Under these conditions no energy is absorbed in the gradual breaking through of the air. On the contrary energy is statically stored in the spheres, and is available to puncture the air.

As regards our recent discovery that spheres are really better than needle-points, you must realize that that applies only within a certain range of voltage. Probably for low voltages, up to 20,000, the needle-gap will remain the standard, because the sphere gap at these low voltages is so small as to be inaccurate, owing to the fact that any arcing at the surface of that sphere, which is negligible in its effect at distances corresponding to 100,000 volts, is fatal and entirely changes the disruptive voltage when you come to 2000 or 3000 volts.

That explains why in those early days where the range up to 20,000 volts covered practically the entire important field of high voltages, when you carefully studied the relative advantages of the needle-gap and sphere gap in the early 90's, the general consensus of opinion was that the needle-gap was the only one which could be considered, because it was definite and was of a length, which is measurable, ranging from 5 mm. to 20 mm. But that very advantage becomes a fatal disadvantage when you are dealing with a half million volts or more, and the needle-gap becomes many feet in length. You then have to build a specially large structure to accommodate the spark-gap, and you have to dissipate so much energy in the corona, before you get a discharge that it requires very large apparatus, very large time lag, and a smaller energy oscillation which is not observable at all. It is merely a question of the relative value of voltages

whether the sphere-gap or needle-gap is preferable. At lower voltages we do not recommend changing from the needle-gap to the sphere-gap, but when you come to voltages of such magnitude that the sphere gap is a measurable length, then the sphere gap is the more reliable and the more workable method.

C. Fortescue: I think that Dr. Steinmetz has summed up the attitude of those who have recommended the spark-gap very thoroughly. There are one or two points in this spark-gap paper of ours that I want to call attention to. We say: "The effects of atmospheric pressure and humidity have also had only a negligible effect on the break-down voltage." I want to correct that statement and say that what we meant was this; that during the time we made the tests the change in temperature and atmospheric pressure was too small to produce an appreciable effect.

I would like to say a few words in regard to Mr. Layman's experiment some years ago in which he found those discrepancies. I think the discrepancies were due to the fact that the spheres were so good; in other words, oscillations which take place in any commercial circuit will break down the sphere-gap, where they might not break down the needle-gap, and I think that is probably the cause of his discrepancies. We found when we had a circuit that was kept very steady, and carefully observed, that all the points were consistent throughout, but we happened to work part of the time on a circuit on which some cranes were operating, and every time a crane started or stopped it produced a surge which would break down the spark-gap, and that was noted time and again, and pointed plainly to the fact that the slow surge set up by the starting current of the crane caused an oscillation which, at the peak of the wave, produced a superimposed ripple which broke down the spark-gap.

C. E. Skinner: I want to add that the very fact that the sphere gap does break down, due to these surges, is a distinct advantage in its use for measuring voltages where we are dealing with insulation, because it is these same surges which break down the insulation.

Percy H. Thomas: I think that Dr. Steinmetz has put this thing in pretty nearly its true light. It does require energy to cause a discharge through air, but it seems to me reasonable if we can apply the requisite amount of energy in a very short time, no matter how short, we can get the discharge in that time. Taking that point of view, we have only to consider how much energy has to be put in and how quickly it can be supplied. As Dr. Steinmetz pointed out, the electrostatic charge on the sphere-gap does supply stored energy very close to the break down point, and is thus able to maintain a difference of potential rigidly at that point.

The amount of energy which it takes to start a discharge through the air, will I think, be found to be very small. The discharge is started by the velocity produced in the electrons,

and it does not take much time to start the cumulative liberation of more electrons. Furthermore, the time that it takes to produce such motion must be extremely minute, since these very light bodies have to move only a very short distance.

L. W. Chubb: Dr. Steinmetz has mentioned his experiments made to find out whether a single impulse of voltage would break the same air gap as a continuously applied voltage. The authors conclude that the break is a function of time, but I believe that the maximum peak of the impulse voltage was the true variable. I would like to ask Dr. Steinmetz whether this impulse voltage could not have been very much in error due to the flux lag, eddy currents in the core, and leakage reactance, in such a transient test.

Charles P. Steinmetz: I think I can explain that this phenomenon could not have been present, because whatever magnetic effect eddy currents in the iron can exert, would be exerted on the primary and secondary of the transformer simultaneously. The counter e.m.f. appears instantly in the direct current primary supply by the closing of the switch, and therefore it must have appeared instantly in the case of the secondary. The only source of error which might exist would be the distributed capacity of the secondary winding, and that can be calculated, but in these particular transformers we measured the distributed capacity, at least the magnitude of it, and so knew in which condition of test that effect was negligible; that is to say, negligible within the errors of test, a matter of 10 per cent, more or less.

Since that time we have repeated some of our tests and have taken an oscillogram of these waves, that is, these single impulses, and we employed so much more energy that you can in the oscillograms, see the effect of the initial rapid rising and tapering off the impulses. We checked up that phenomenon, and while there is some error, the error is of very small magnitude indeed.

L. W. Chubb: I would also like to ask Dr. Steinmetz whether the sparking distances and size of terminal were such that they worked above the corona point?

Charles P. Steinmetz: Most of them were above the corona point. Some of them, those with spheres, were below the corona point. At that time, which was before the investigation of corona made with Mr. Peek, we did not specially register that, but my impression is that in previous cases we did observe marked corona, and previous to that we arranged the curve of sparking distances between the spheres, so it appears that at the circumferential condition, with very sharp and marked break in the characteristic of the disruptive strength curve, which is observable, that in the case of the sphere gap at that point the corona begins. I think corona has a material time-lag resulting from its energy-lag, but that phenomenon requires still further investigation. We have started some investigations trying to study this form of corona, but have not proceeded far enough yet to arrive at any satisfactory results.

J. B. Whitehead (by letter): There will be little dissent from the opinion of the authors that the needle point air gap as at present described by the A.I.E.E. Standardization Rules is an inconsistent and unsatisfactory standard for voltage measurement. In support, however of that much abused apparatus it may be pointed out that the standardization rules have apparently not taken proper account of the best information and study of the needle gap as a means of measurement of voltage. The instrument has been studied somewhat extensively by W. Weicker and his results published in the *Electrotech. Zeitschrift* in 1911. Without in the least advocating the needle gap as a standard, it may be pointed out that it has now been shown that the needle gap gives widely varying results below 60,000 volts, but that above that figure under uniform external conditions the results are very constant, provided the angles of the points are chosen between 20 deg. and 100 deg. Sewing needles, therefore, if used in the spark gap introduce a source of error which it would be fairly easy to remove by stipulating a wider angle for the point.

The use of the sphere gap was suggested by Alexander Russell in 1907 as a satisfactory arrangement for testing dielectric strength. In an earlier paper, referred to by the present authors, he attempted to reduce the formulas of Kirchhoff for evaluating the electric intensity between the spheres. In this way he aimed to present ready methods for calculating the voltage at which a given sphere gap would break down.

He also worked out a number of cases from the simpler though still somewhat unwieldy expressions and presented them in the form of a table for reference. Subsequently Russell's discussion and results were attacked by de Kowalski and Rappel in an article in the *Philosophical Magazine* for 1909, in which they presented a number of careful measurements with alternating voltages. They used spheres up to 30 cm. diameter but did not carry the width of gap above 2 cm. Russell has presented two other papers dealing with the sphere gap to the Physical Society of London, which have been presented in the Proceedings of that Society for 1911. The result of the discussion so far is that there is considerable doubt as to whether the electrical intensity within the sphere gap may be accurately calculated and the fact that measurements of different observers show a rather wide discrepancy.

The authors have not in my opinion strengthened the case for the sphere gap. They have made an important contribution to the experimental knowledge of this instrument, but their paper hardly presents a sufficiency of data to warrant the claim that the sphere gap should be used as a standard of measurement. I wish to express my interest and admiration for the ingenious method they have adopted for deriving the maximum value of voltage.

In offering my few criticisms I trust that the authors will realize that they are due only to my conviction that the sphere

gap presents almost, if not quite, the same limitations as the spark gap. First, while admitting possible influences of pressure, temperature and moisture the authors present no data showing the magnitude of the influence or the absence of influence of any one of them. Second, the influence of proximity of extraneous objects is granted by the authors and suggestion made of various screens and future measurements to study this influence. Third, little if any statement is made of the degree of accuracy with which the observations may be repeated. In fact in this connection the single values as given in the tables show discrepancies in many cases of an order of magnitude of from 1.5 to 2.5 per cent; *e.g.* with the 25-cm. spheres for the gaps of 4 cm. and 11 cm., for the 37.5-cm. spheres the gap at 5 cm., and with the 50-cm. spheres the gaps at 8 cm. and 12 cm. have been selected without any close scrutiny of these tables. Although the range in which the authors' observations coincides with those of de Kowalski and Rappel is very narrow yet there is a considerable discrepancy in the values obtained.; *e.g.* for gaps of 1.35 and 1.23 cm. and 30-cm. spheres the results of the latter experimenters show 37.5 and 34.6 kilovolts respectively. The present authors also fail to interpret the symbols at the tops of their tables. It would be interesting also to know by what method they arrive at the figures of electric intensity as given in Fig. 4.

The principal objection to both the needle gap and the sphere gap in my opinion lies in the fact that they do not take advantage directly of natural constants. It has been amply shown now that the electric strength of air depends markedly on the distribution of electric intensity in relation to the volume of air. For this reason it has heretofore proven impossible to present a certain method for calculating length of a needle or sphere gap to break down at a definite value of voltage. On the other hand the use of the appearance of corona on the interior of two concentric cylinders obeys a law upon which close agreement now obtains among many observers. The influences of pressure, temperature, moisture have also been studied with resulting good agreement. It is therefore possible to write down at once the dimensions of a concentric cylinder measuring apparatus which under given conditions of temperature and pressure will develop break down at the surface of the inner conductor at a given voltage. The objections to this method are the difficulties of observing the point at which corona starts and the necessity of changing the inside cylinder for different voltages. The first of these objections is not a serious one and it is my hope soon to present to the Institute a paper describing the adaptation of the above principle as a means of measuring voltage. For over two months daily observations have shown a consistency under widely varying atmospheric conditions to within less than 1 per cent.

F. M. Farmer and E. D. Doyle (by letter): This proposal to measure the deviation of the wave form of an alternator from a

pure sine wave by means of condenser reactance appears to be so simple and practical that one wonders why it has not been suggested before. The present Institute standard is indeed unsatisfactory, as it not only does not penalize the harmonics in proportion to their undesirability but is cumbersome and expensive to apply.

The reason for using a large inductive reactance to determine the standard value is not apparent. It would obviously seem more simple to use a condenser of known capacity in which case the sine wave reactance is of course simply $X_s = \frac{1}{C\omega}$. The distortion ratio would be obtained by the simple measurement of the condenser reactance on the distorted wave.

TABLE I

(a) Measurements on a badly distorted wave *without* voltage transformers.

Test No.	Capacity microfarads	E.m.f. volts	Current milliamperes	Distortion ratio
Ammeter—Weston 7.5 volt dynamometer type voltmeter No. 3201. Resistance 55 ohms, inductance 19 millihenries.				
1	1.959_5	107.2	8.13	1.02_6
2	1.007	122.9	8.0	1.71_5
3	1.007	114.8	9.04	2.07_3
4	1.007	129.4	11.47	2.33_5
Ammeter—Weston 7.5 volt dynamometer type voltmeter No. 6776. Resistance 93 ohms, inductance 19 millihenries.				
1	1.007	107.0	41.4	1.01_8
2	0.603_3	122.1	47.4	1.70_4
3	0.603_3	114.5	53.9	2.07_0
4	0.603_3	129.4	69.1	2.34_4
Ammeter—Weston soft iron type milliammeter No. 435, 74 milliamperes. Resistance 101 ohms, inductance 292 millihenries.				
1	1.007	106.7	42.8	1.05_6
2	0.454_1	122.1	40.7	1.94_8
3	0.454_1	144.5	65.1	3.32
4	0.454_1	128.7	74.6	3.38_2
(b) Measurements on a badly distorted wave with voltage transformers.				
Voltage stepped up and stepped down with two 6600-110 volt, 200-watt voltage transformers. Ammeter, Weston voltmeter No. 6776.				
1	0.603_3	105.2	24.3	1.01_4
2	0.603_3	120.6	46.9	1.70_6
3	0.603_3	112.3	53.2	2.08_2
4	0.603_3	126.1	67.4	2.34_8
Voltage stepped up and stepped down with two 2200-110 volt, 50-watt voltage transformers. Ammeter, Weston voltmeter No. 6776.				
1	1.007	109.0	42.1	1.01_7
2	0.603_3	123.9	48.1	1.70_7
3	0.603_3	117.1	55.8	2.09_5
4	0.603_3	130.4	70.1	2.36_3

Test No. 1, fundamental only, (60 cycles).
Test No. 2, fundamental with 53.5 per cent third harmonic.
Test No. 3, fundamental with 37.5 per cent fifth harmonic.
Test No. 4, fundamental with 53.5 per cent third harmonic and 37.7 per cent fifth harmonic.

As the convenience of the application of any new standard is of great importance, it occurred to the writers that some figures taken in actual measurements would be of value, since Mr.

Davis has not given any figures indicating the magnitude of the quantities with which he had to deal in obtaining the values that he gives in his paper. Furthermore, two questions arise in the application of this method which made it desirable to make some tests. First, is it practicable, in order to avoid the use of large condensers, to use ammeters of small range without introducing too much resistance and inductance in series with the condenser? Second, can the distortion of high-voltage machines be measured by using small capacity (voltage) transformers?

TABLE II

(a) Measurements on a moderately distorted wave without voltage transformers. Current measured with Weston voltmeter No. 6776.

Test No.	Capacity microfarads	E.m.f. volts	Current milliamperes	Distortion ratios: By calculation*	Distortion ratios: By measurement
1	1.007	119.5	47.5	1.04_2	1.04_6
2	1.007	118.7	51.4	1.11_8	1.13_4
3	1.007	120.2	53.5	1.15_2	1.17_2

(b) Measurements on a moderately distorted wave with voltage transformers. Current measured with Weston voltmeter No. 6776.

Test No.	Capacity microfarads	E.m.f. volts	Current milliamperes	Distortion ratios: By calculation*	Distortion ratios: By measurement
Voltage stepped up and down with two 2200-110 volt, 50-watt, voltage transformers.					
1	1.007	116.4	46.4	1.04_2	1.04_4
2	1.007	116.4	50.3	1.11_8	1.13_6
3	1.007	116.8	52.1	1.15_2	1.17_2

Test No. 1, fundamental with 10.2 per cent third harmonic.
Test No. 2, fundamental with 10.2 per cent fifth harmonic.
Test No. 3, fundamental with 10.2 per cent third harmonic and 10.2 per cent fifth harmonic.

NOTE: "Calculated" values of distortion ratio obtained as follows:
For fundamental wave $R = 1.00$ by definition.
For distorted wave,

$$R = \sqrt{\frac{E_1^2 + (3E_3)^2 + (5E_5)^2}{E_1^2 + E_3^2 + E_5^2}}$$

where E_1, E_3, E_5, are mean effective voltages of fundamental, third harmonic and fifth harmonic respectively.

* Sign wave assumed. Oscillograph tests of the charging current of a condenser showed that the fundamental is not a perfect sine.

Tables I and II show results of tests made at the Electrical Testing Laboratories with various distorted waves with and without voltage transformers. A high grade sub-divided mica condenser was used and the current was measured with different types of ammeters.

These results lead to the following conclusions:

1. As is to be expected, milliammeters of the soft iron vane type have too much inductance. The inductive reactance becomes appreciable so that the voltage across the condenser is no longer

equal to the generator voltage. Therefore, in order to use an ammeter of this type it should not be less than 250 milliamperes range and suitable indications on such an instrument would require about 10 or 12 microfarads capacity at 25 cycles.

2. Voltage transformers of as small as 50-watts capacity can be used for stepping down the voltage without introducing an objectionable error.

3. All that appears to be necessary to obtain the distortion ratio of any machine as defined in the proposed definition is a standardized sub-divided mica condenser of one or two microfarads capacity, a 100 milliampere ammeter with low inductance such as a dynamometer or hot wire instrument, a voltmeter of any standard type, a standard voltage transformer and a speed counter. The condenser should obviously be a high grade one in which the phase angle is within a very few minutes of 90 deg.

Charles P. Steinmetz: The purpose of Mr. Davis's paper, is to recommend the establishment of a wave standard which shall be based on the distortion ratio; that is, on the ratio of the current taken by a condenser with the distorted wave and the current which the same condenser would take with a sine wave. Mr. Davis's paper also suggests a method of obtaining the distortion ratio, where the alternator is not accessible. This condition exists when you are considering a commercial circuit, as, for instance, in my laboratory. Under such circumstances it is not always practicable to determine the exact frequency. You can use the same wave with the same frequency, smoothing out the higher harmonics by high inductance. The natural way, where you have a generator available, would be to measure capacity, with a condenser and have the capacity exactly known, and measure the current input at measured voltage, and also measure the frequency.

Naturally, what we are interested in is the voltage wave as it exists during all conditions of operation, not only at full load, but at no-load. Thus it would be very nice to standardize and specify that the voltage should be taken at no-load as well as at full load, and, more particularly, at condenser load, where the distortion is probably greatest. The only trouble is we have already spent much time in the discussion of "equivalent" loads and it will be agreed that the subject presents grave difficulties. You see the importance of specifying a wave test at full non-inductive load and at full condenser load, where we are discussing means of getting equivalent load tests and equivalent heat tests. Even though we may know the condition, which we should desire, we cannot load the generator, because we do not have the power available. Zero power factor load naturally does not mean anything here, because while it may be leading current it is not a condenser load, and does not exaggerate the harmonics. Thus the only practical solution seems to consist in assuming that the different harmonics which appear under load, would probably be there at no-load, and would show the distortion ratio of the no-load wave. It might be exaggerated

at full load, especially condenser load, but we merely make allowance for that by specifying a low enough distortion ratio.

The fact is that the only additional harmonics which should appear under load are probably those resulting from the field distortion. Field distortion is the effect of non-inductive load. We do not much care for the harmonics, because a non-inductive load is equivalent to a resistance load, where the current follows the energy wave, and whatever distortion the voltage wave may have it would not have any serious effect. The case where harmonics are apt to be objectionable is mainly where the load is such as to exaggerate them, condenser load, and in that case the armature reaction is not distortional, but magnetizing, and therefore it is not practical to introduce additional harmonics. We thus see that we can get from the noload test some good indication of the wave shape which we will need in practice. This appears to be the only test which is practically feasible.

B. G. Lamme: Mr. Foster's paper shows a great number of wave forms of different generators. Apparently one object of the paper is to show what variations seem to be permissible in good practice. It is a fact that many alternators working today without any trouble whatever, have what appears, to be very bad wave forms. It is only in special cases that wave forms give any particular trouble, and sometimes the cause of the trouble does not really lie in the machine itself, but the bad wave form in connection with external conditions may result in disturbances in the system.

It is an old, well known fact that any symmetrical wave form can be split up into a fundamental and harmonics of the odd order. A wave form obtained by means of the oscillograph may show us by analysis what harmonic is sufficiently large to cause disturbance, but it does not show us how to eliminate the harmonic. There are some suggestions in Mr. Foster's paper as to how this can be done by distributing the windings differently, or by differently shaping the poles. However, shaping the poles by blindly cutting off what one thinks should cure the trouble, is a dangerous proceeding, as this might result in exaggerating the very harmonic that it is desired to eliminate. In order to shape the poles to obtain the desired result, it is necessary to predetermine the diagram representing the field flux distribution, that is, the field form; and from the study of this and its relations to the e.m.f. wave, one can determine pretty definitely just what change is necessary to eliminate any particular harmonic.

I note that Mr. Foster mentions a hunting tooth to eliminate harmonics. I wish to call attention, however, to the fact that with a polyphase machine, one should be careful in using a hunting tooth, or an exact symmetry of phases will not be obtained. In three-phase machines, three hunting teeth should be used in order to obtain symmetry. One hunting tooth will not give the desired result.

A. E. Kennelly: In regard to Mr. Davis's paper, the plan presented therein seems to be a great advance over that offered in the existing Institute rule for determining wave form. The existing rule calls for determining the wave shape, then determining the corresponding equivalent wave shape, superimposing the two and measuring the greatest difference. That is a tedious operation which involves a considerable amount of personal equation. This proposed plan seems much more definite, more easily accomplished, and much more simple. It is, however, as has been before suggested by Dr. Steinmetz, a little indefinite in that it calls for the measurement of reactance in a condenser, and that suggests measuring the length of a bar, by measuring the volume of the cubical bulk whose side was the length of this bar. Would not it cover all the purposes Mr. Davis has in mind, if we were to define simply the distortion ratio of a voltage wave, as the ratio of the current produced by that voltage in a condenser to the current supplied in the same condenser from the sinusoidal e.m.f. of the same root-mean-square value. That definition would call for a standard condenser of specified dimensions, perhaps a standard frequency meter, a standard voltmeter, and a standard ammeter. By these instruments the measurements could be made without involving the definition of reactance in certain condensers.

M. G. Lloyd: Most of us are agreed that the present rule defining the limit of tolerance to departure from the sine form of wave is unsatisfactory, and Mr. Davis has given a possible substitute for it. All three papers point out that the present rule does not sufficiently penalize the higher harmonics under certain practical cases, such as the charging current on a transmission line. There are other cases, also, where the higher harmonics have greater importance than the rule gives to them, as, for instance, in eddy-current effects where they are large enough to make ripples in the flux wave. In other cases, however, it is not the higher harmonics which are most objectionable. In the case of hysteresis loss the lower harmonics are more detrimental than the higher harmonics, if compared on the basis of their equivalent value, as given by Mr. Davis's rule, that is, assuming them in inverse proportion to the order of the harmonic. It must be obvious then that in some cases this distortion-factor is a desirable criterion, while in other cases some other property of the wave is of greater importance, such as a form-factor; and in still other cases, perhaps an amplitude-factor or crest-factor.

While I am hardly ready to indorse the suggestion of Mr. Davis, it does seem better than the present rule. If the distortion-factor is to be made the measure of sinuosity, I should like to make the suggestion that the limit of tolerance suggested by Mr. Davis be cut down. I think he is entirely too liberal in defining what we shall accept as sufficiently close to a sine wave, or what may be called a conventional sine wave. To illustrate this I have computed the values in the accompanying

table, applying this limit of tolerance to the single case of hysteresis loss, such as would occur in the core of a transformer, since this is one of the practical cases to be considered in weighing the effect of departure of the wave from the sine shape.

In this table the percentage variation in hysteresis loss is given for the case of a single harmonic (a frequency three or five times that of the fundamental) for the two extreme cases where the phase angle is such as to produce the greatest increase and the greatest decrease in the wattage. The last column in the table gives the range in hysteresis values possible for the case of the third or fifth harmonic and the particular values of distortion ratio indicated.

CHANGE IN HYSTERESIS FOR THIRD AND FIFTH HARMONIC HAVING EXTREME VALUES OF PHASE ANGLES—FOR GIVEN DISTORTION RATIO

Distortion ratio	a	Order of harmonic	a/n	Increase in per cent	Decrease in per cent	Range in value possible, per cent
1.05	0.342	3	0.114	5.0	6.7	11.7
		5	0.068	1.6	2.6	4.2
1.10	0.493	3	0.1 4	6.5	10.8	17.3
		5	0.099	2.2	4.0	6.2
1.15	0.615	3	0.205	7.5	13.5	21.0
		5	0.123	2.7	5.3	8.0

It is seen from this table that if we allow a distortion ratio of 1.15 it is possible, with the third harmonic alone present, to have a hysteresis loss differing 13.5 per cent from the value with a sine wave, and in the case of the fifth harmonic the difference may be 5.3 per cent. The possible range in value is 21 per cent for the third harmonic, and eight per cent for the fifth harmonic. Even with a distortion ratio of only 1.10, the range for the third harmonic is 17.3 and for the fifth harmonic, 6.2.

The table illustrates that in the case of hysteresis it is the lower harmonics that are most objectionable, and it also illustrates, in my opinion, that the permissible allowance suggested by Mr. Davis is too great to come under the definition of a sine wave. If we should make a distortion ratio of 1.05 the limit of tolerance in a sine wave, it will be seen that the range in the value of hysteresis possible with a third harmonic is 11.7 per cent. It consequently seems desirable to me to limit the conventional sine wave to this value.

In adopting such a limit it is not a question of choosing a figure which will bring the best generators or other apparatus within the limit, for it is not necessary that a good machine be considered as giving an approximately sinusoidal wave. To

cut down the limit merely means that instead of being able to say that a certain generator gives a sine wave within the limits of the Standardization Rules we should have to say that it exceeds the limit by — per cent. The only reason I see given by Mr. Davis for such a wide latitude for distortion ratio is the fact that the average for 22 commercial alternators was 1.135. In my opinion the object in defining a sine wave should not be to make the average commercial alternator meet the definition.

While on three-phase circuits the third harmonic does not appear and the range in hysteresis value with the fifth harmonic would not be greater than eight per cent with a distortion ratio of 1.15, we should bear in mind that our definitions are not to be confined in use to the most common commercial conditions, but must be applicable to any case that may arise.

L. W. Chubb: Dr. Lloyd has covered about what I was going to say in regard to the low harmonics.

I think that it is a mistake to set a new standard of wave shape which penalizes the higher harmonics, in order to reduce transmission troubles, and disregards the low harmonic distortions which affect iron losses and in some cases prevents satisfactory parallel operation.

The paper starts with three objections to the present specification, which are not valid if the tester knows how to take wave-shapes and check them up according to the present specifications.

In answer to the first I would say that any maker of machines under a wave shape specification should have an oscillograph available. The oscillogram of the voltage wave can profitably be used for record, and to check the design, as well as to show that it meets the specification.

I object to the second objection because it is not necessary to measure any ordinates to obtain the equivalent sine wave. This I will show later.

I object to the third objection because no trial calculations are necessary to determine the position of minimum maximum deviation, nor is it necessary to plot any curves except to draw a circle of a certain diameter with an ordinary compass.

Suppose the wave shape in question is a polar curve. Its area which is proportional to the root-mean-square value can readily be measured with a planimeter and the equivalent sine represented by a circle of the same area. This circle drawn on a piece of thin or transparent paper, should be placed over the polar curve of the wave in question and a needle should be driven through a point on the circumference of the circle placed over the pole of the other curve. The small piece of paper is then to be moved around the needle as a pivot until the minimum maximum deviation between the two curves measured on a radius vector is obtained. This difference expressed in per cent of the diameter of the circle is the final result.

The polar curve can be obtained by a special mechanical tracing table if the original record has been taken in rectangular

co-ordinates. But it is better to take the picture in polar form at once by revolving a celluloid disk film at synchronous speed in front of the slit of the oscillograph. The latter method, of course, eliminates the tracing operation, which is apt to introduce error.

The new wave shape standard proposed by Mr. Davis and the test method to be used give the designing engineer no idea of the resulting wave. All he will know is whether his machine meets a certain ratio. If his machine fails to show the specified ratio he will want to know why, and what can be done to reduce the harmonic distortions. If an oscillogram of the wave is taken, all of the necessary information can readily be obtained and a permanent record of the wave can be kept on file for future reference.

Mr. Lamme forgot to mention one source of quite serious harmonic distortion—that which is caused by the total flux pulsation in the machine.

If the number of teeth is divisible by the number of poles there is a pulsation of the air gap reluctance under each pole and as these pulsations will all be in phase, the total flux in the machine will pulsate, and cause decided ripples, in the voltage wave. If the teeth per pole is an even number, this ripple will be composed of the odd harmonics next above and below this even component. In other cases it may be of tooth frequency or composed of the two odd components on each side of double tooth frequency.

Except for these tooth pulsations the wave shapes of machines can be quite accurately obtained from the designers plot of the field form.

We find that the most satisfactory way to examine the wave shape of a generator is to take the oscillogram and find out not only how much distortion there is but where the distortion is and what the cause is.

Oscillograms can profitably be taken and analyzed in all cases in which there is any question regarding the wave shape.

Good wave-shape design is a matter of evolution. Improvement comes from the study of the actual waves of the machines.

Accurate harmonic analysis can be made by taking the oscillogram on a disk film run at synchronous speed, printing it on a zinc disk, etching the line into the disk and placing this etched record on the table of a mechanical harmonic analyzer, and turning a crank. We have recently made up such apparatus and can analyze a wave in a few minutes direct from the oscillogram and without any manual tracing.

The present specification does not sufficiently limit the high harmonics. The proposed standard will more than correct this fault, but allows too much latitude for the low-frequency components and takes no account of the phase relation of these low components.

This method of analysis is more applicable to the examination of wave shapes on finished machines, but can be applied in design

before the machine is built if the designer wishes to go to the trouble of analyzing his field form and adding this result trigonometrically according to his chording and winding. This latter method has not been found practical but has some advantages over the method of predicting the wave shape by adding the field forms at a finite number of ordinates.

Comfort A. Adams: In regard to the pulsations of flux which have been mentioned, there are two varieties due to tooth variations of reluctance in the magnetic circuit. One affects the conductors in between the poles and puts kinks into the steep part of the wave. This does not affect the conductors under the center of the pole, or produce kinks in the peak of the wave. The other is a variation of flux distribution rather than a pulsation of flux in the whole magnetic circuit. It is sometimes called the flux swing, and affects the conductors under the center of the pole. It thus puts kinks into the peak of the wave. These two sets of kinks are of the same frequency and may both occur in the same machine, but they are not generally in the same phase, consequently it may appear, in counting the kinks in a wave, that you have an even number of kinks, but in analyzing these you will find that they actually produce odd harmonics in the theoretical sense of the term. The reason for this is that each set of kinks constitutes a tapering even harmonic which when analyzed gives two odd harmonics, one of the next higher order and one of the next lower order.

However, as Mr. Lamme has said, in the vast majority of turbo-alternators, as well as in many other machines, the air-gap is so long in proportion to the slot opening, that these pulsations are not appreciable.

Also, if it is desired to eliminate this effect, it is a simple matter to do so, by having a fractional number of teeth per pole. It has been shown in Mr. Foster's paper that such a change actually eliminates the harmonics in question.

The reason for this is very simple, namely, that in this case the several conductor belts of a given phase are not located in exactly the same position with respect to the poles under which they happen to be at the instant under consideration. It can be easily shown that a fractional number of slots per pole per phase is equivalent to a much larger number of slots per pole per phase as far as the wave shape is concerned, *e.g.* $1\frac{1}{4}$ slots per pole per phase is practically equivalent to 5 slots per pole per phase, $4\frac{1}{4}$ to 17 and so on. It is thus a simple matter to wipe out all tooth kinks even when the gap is short and the available number of slots small.

Mr. Chubb has pointed out a method of computing the harmonics of the e.m.f. wave from the analysis of the flux distribution curve. Much time may be saved in this method by making use of carefully computed tables which will be found in a paper which I read before the Institute on the subject of "Alternator Wave Shape," nearly four years ago.

It would seem therefore that there is little excuse for building

alternators which do not conform more closely to the sine wave than suggested by Mr. Davis. On the other hand it should be remembered that the object of a rule of this sort is, simply to set an upper limit for general purposes, and not to write specifications for the consulting engineer. If the case requires a closer conformity to a sine wave, it can be so stated in the specifications. Even some other form of test such as an oscillogram may be specified, where more information is desired. The important consideration in connection with the Standardization Rules, is to have a simple definition of wave form deviation which can be applied by a simple test, and which will be as nearly as possible a measure of the undesirability of the deviation.

In the case of multi-circuit windings, it is important that the circuits connected in parallel should be of the same phase and wave shape; but this is not always possible with a single hunting tooth, as Mr. Lamme has pointed out. It is possible in many cases however, with a fractional number of slots per pole per phase.

It is entirely possible so to design an alternator that its no load wave shape will approach the sinusoidal as closely as it can be measured by any method; and so that it will substantially maintain that wave shape under all conditions, of load, single-phase or polyphase, barring the effect of an excessive current distortion produced externally to the alternator, which absorbs an e.m.f., which, subtracted from a sinusoidal generated e.m.f. wave, leaves at the terminals a slight distortion.

Paul M. Lincoln: I want to call the attention of the Committee to a piece of constructive criticism in Mr. Davis's paper. Here is a proposed method of judging wave shape, which I think is a distinct advance on what we had before. It is a method of measuring wave shapes, which takes cognizance of the higher harmonics and penalizes them in the order of those harmonics. That is a feature in the determination of wave shape which we have not had heretofore, and which is a very valuable thing to have.

Some critics have expressed the fear that this allowable latitude given by the proposed factor, 1.15 is too large. I am not prepared to express a definite opinion on the exact size of that factor; it may be that further investigation will make it desirable to make some slight modification in its exact value. In this connection we might cite the table appearing in this paper, in which 22 machines are listed. Of these 22 machines three have a form factor above the suggested limit, 1.15. If this list of machines is typical of the ordinary run of machines that come along, I think the rejection of 15 per cent of them indicates we have a fairly close limit.

Another fear has been expressed, namely, that the latitude allowed in the lower harmonics is so great as to make a variation in form factor which may give rise to considerable variations in the iron losses of transformers. The one which has been stated

particularly, is the variation in the third harmonic. So far as the third harmonics go, I think we can forget them, because there are practically no third harmonics. In dealing with three-phase circuits we do not get third harmonics in the circuit from one terminal to another. They cannot appear in those circuits, and since practically everything is three-phase, we are reasonably safe in neglecting the effects of third harmonics. Therefore, the fifth harmonic will be the first one which comes in to affect the form factor, and the fifth harmonic, entering to the maximum extent it can under this rule, will not have a very large effect on the iron losses of transformers.

Charles P. Steinmetz: The determination of the wave shape by an oscillogram, the resolution and separation of the higher harmonics, the study of their origin and their elimination, for giving the designer data by which to design machines of good wave shape, is one thing. But to provide a specification to determine by some simple test whether an actual machine will operate satisfactorily in commercial service, and therefore is acceptable, is quite another thing.

The paper deals with the latter consideration. It does not deal with the study of wave shape for the purpose of obtaining the sort of information required by designing engineers. That we have to consider. With regard to the discrimination against higher harmonics, as far as I can remember at the present time, the only condition under which harmonics of the wave are harmful in an electric circuit, is in the case of transmission lines and underground cable systems, that is, in their relation to the capacity, of the circuits, and there the harmonic is approximately proportioned to the frequency. Consequently the proposed new standard, provides an appropriate criterion. It is not correct to say that the lower harmonics are harmful regarding hysteresis losses. It is not the harmonics there, but the crest value of the voltage wave, which is of significance. That, however, is not determined by the wave shape specification to within 10 per cent for the sine shape alluded to. That may mean a peaked wave or a flat-topped wave, and between the two the difference in core loss is about 36 per cent. So you see that is another question, which is not dealt with in the wave shape specification.

In regard to latitude, the old rules specify that the deviation shall not exceed 10 per cent from the sine shape. It appears to me that to obtain an equivalent with the new specification, we would have to take at random a large number of machines, see how large a percentage of them fall outside the former specification, and ascertain on the new basis the limitations which would result in approximately the same percentage of machines falling outside of the specification. That would give you the equivalent. Then we may consider whether we are ready now to draw the lines closer, make more rigid specifications, and either say (in the terms of the old rule) that the machines must

be within 5 per cent of sine wave, or, (in the terms of the new rule), that the distortion factor must not exceed 1.10. That, however, is entirely aside from the question of the suitable specification for determining the distortion factor.

Charles F. Scott: It seems to me, repeating what others have said, that the means herein given of having a simple practical determination of the variations from sine wave, is an admirable one. However, there may be a case in which machines which may fall within the limitations of the paper may, have differences of importance. This test does not indicate whether a single harmonic may cause the limit to be nearly reached, or whether it may be a combination in minor degree of several harmonics. The question then may arise whether the objectionable result of variation from the sine wave may not come from the preeminence of some particular harmonic: For example, one thing in which harmonics may be objectionable is in the induction caused in other circuits. Supposed induction is caused in a telephone circuit. If the harmonic be near the fundamental, say the fifth, it may be too low to cause a disturbance. If it be a high harmonic, several times that frequency, such as the eleventh or thirteenth or higher, then if this permissible limit is nearly reached by the predominance of one high harmonic, a disturbance may result which might not have occurred if the harmonics had distributed throughout the whole range. I bring this point up to illustrate that while the specification is good as far as it goes, there may be cases where it does not cover everything.

L. T. Robinson: Some have urged objections against this method, because it apparently is more complicated than it would be to take the calibrated condenser. I think the proposed method is all right; it makes use of the voltmeter and ammeter, things we are familiar with, and which we know have a certain degree of permanence, as against a condenser which may be permanent to a certain extent, but I do not believe is in the same class as the instruments. Therefore, it is not a complication, but a matter of simplicity.

M. G. Lloyd: I agree with Dr. Steinmetz that it is not a question of whether the departure from the sine wave is harmful or not. In the case of core loss it may be either harmful or beneficial, depending upon the phase of the harmonic. It is a question of how close the wave must be to a true sine wave. If you specify for a transformer a certain core loss, are you satisfied to come within 13.5 per cent or even five per cent of the value you would have with the sine wave?

Taylor Reed: The measurement of wave records is assumed, or authorized by implication, in the Standardization Rules, where a deviation from sine wave of 10 per cent is designated as ordinarily permissible (79, 80, 5c–j). Method and apparatus for determining the deviation, as defined and limited, properly come in for consideration. In measurement of wave records at the present time practise is probably very diverse, and it is

desirable that the measures should be adequate and that those who use them should have a proper understanding of their degree of reliability and accuracy.

The condenser charging current referred to prominently in Mr. Davis' paper is a useful aid in detection and analysis which has received too little attention. Its effect in making prominent the harmonics is well illustrated in the figures of the paper (Figs. 1 and 3) appears particularly well in case only one harmonic is present in appreciable amplitude. It is also useful as a detector of very small deviations or imperfections in exceedingly good waves where the departure from the sine wave is so small as to be within or near the limit of accuracy of direct wave measurement.

Mr. Davis describes in his paper an interesting combination of condenser and reactance coil by which the reactance of the condenser for generator wave and for sine wave are made directly comparable. The proposed rule based upon its use tests the generator wave without specific knowledge of the form of the wave: it differs radically from the present rules, notably in penalizing the higher harmonics. The paper does not describe means of transfer to the proposed rule from the present, or correlation between them, as for instance comparison under the proposed rule of a generator of new design with a previous generator for which only the wave record might be available, if made by computing the harmonics and magnifying them in proportion to their order would probably not be reliable or closely made.

The proposed rule, and the apparatus it describes, provides a criterion for waves which is good in many respects. It should be placed under varied and extended test under all possible conditions that have to be met, and its adoption should await general acquaintance on the part of those who would have to apply it, and adequate demonstration of practicability.

The caution Mr. Davis expresses about restricting the wave testing combination to a small part of the rated generator load, which might properly be incorporated in the proposed rule, is very pertinent in view of the excessive sensitiveness of some generators to wave distortion even under small fractional loads. In fact, the load waves at various power factors are of such practical importance that the Standardization Rules seem distinctly incomplete in declaring a generator acceptable on a fair no-load wave, however distorted its load waves may be.

Mr. Davis's apprehension of lack of means of obtaining wave would have seemed more justified some years ago when systems were smaller and more isolated, and when oscillographs were less plenty. In fact, while the amount of material obtained by oscillograph now being presented is considerable, it is impossible for one acquainted with the number of oscillographs in operation and with the character of those who have them in charge not to believe that engineering demands requiring its application are

being adequately looked after: and indeed that, further, a large volume of material has been secured, the presentation of which would contribute to the advancement of the art, and to its beauty as well.

Cassius M. Davis: It might be interesting to know the magnitudes of the quantities used in making the twenty-two tests listed in the paper. The condenser had a reactance, on 60 cycles, of approximately 750 ohms. Inserted in series with this was the inductive reactance to give the sine wave, which had about 3000 ohms. The current measured on the ammeter was in the neighborhood of one ampere, and the voltage across the condenser was approximately 700 volts. The question has been raised as to the use of the inductive reactance in series—that we might as well calibrate the condenser, in the first place. This reactance is used because the idea of the test is to make it as simple and as rapid as possible, to be purely a commercial test; and if further details are required, an oscillogram should be taken.

Dr. Kennelly suggested the ratio of currents rather than the ratio of reactances of the condenser. This would be possible if the voltage were held constant, but it is frequently difficult to do that especially if we are using the reactance in series, therefore we would have to read the voltage and current anyhow, which gives the reactance at once.

Mr. Reed brought up the question of correlation between a test which has been made on an old machine under the old rules and a test which may be made on a new machine under the proposed rules. I have calculated a large number of oscillograms, and by taking the ordinates close enough together, or, as has been suggested, by using an analyzer, the oscillogram can be analyzed with sufficient accuracy, to derive the distortion ratio from it; then the wave shapes of the two machines can be compared.

Comfort A. Adams: While such criticisms as we have heard have their place, it should be remembered that the method proposed is a distinct advance over the old one, both in the significance of the definition of distortion and in the simplicity of the method of measuring it; also that the critics have not yet suggested a better one. Unless we find something still better, this should certainly find place in the Standardization Rules.

F. D. Newbury: I wish to recommend the method of calculation of regulation, advocated by Mr. Field, because it is based as nearly as any method can be on test data. The present rule is not adapted to modern machines or modern conditions. Any method that separates the reactance voltage from the armature demagnetization is a step in the right direction. I believe it is still better if separation by calculation is made unnecessary by the test data, as it is in the method recommended by Mr. Field.

S. S. Seyfert: In Mr. Mortensen's paper, the use of the Kapp or the Potier diagram is recommended for the predetermination

of alternator regulation. During 1908 and 1909, Mr. F. T. Leilich and the writer made a study of this subject. The effects of armature reaction and armature impedance were specially investigated. After passing from one to another of a large number of methods of predetermination, a comparatively simple one was arrived at which gave results checking very closely with those obtained from the direct tests.

The chief faults of the old methods are that they either assume that armature demagnetization may be reduced to an equivalent reactance or that the field current on short circuit is a measure of the true armature reactance. The so-called synchronous reactance obtained from the short circuit test is a fictitious quantity. The reading of the voltmeter across the armature after the short circuit is broken is far in excess of the induced voltage while the current is flowing. When normally loaded, the current of the machine encounters no reactance as large as this. The major portion of the field excitation is directly annulled by the armature demagnetization which is at its maximum value in this case. It seems better, therefore, to compute all voltage drops by using values from the static impedance test which are easily made.

In using static impedance values it is necessary, if accuracy is required, to consider the saturation of the machine, and to remember that, for power factors near unity, the minimum value is more correct, while, for power factors near zero, the maximum should be used. The following figures show the comparative values of the *synchronous* and true reactances of the machine on which tests were made.

Apparent synchronous reactance
($I_a = 30$ amp, $I_f = 1.2$ amp) 6.30 ohms
Real or static reactance (maximum)............... 2.84 ohms
Real or static reactance (minimum)................ 1.92 ohms

In the discussion, Mr. Leilich has outlined the tests required and the essentials of the method. It should be noted that, for any condition of running, the induced armature voltage is found from the terminal voltage by what is virtually the old e.m.f. method excepting that the *static reactance* is used for getting the armature drop. The armature demagnetization is found and reduced to an equivalent field current by what seems to be a rational method.

The accuracy of the method has been checked for all degrees of saturation of the machine and for power factors other than unity. There was no marked failure of the method for abnormal running conditions.

Comfort A. Adams: It should be noted that regulation tests as made with ordinary instruments and by ordinary observers, are more liable to error than a really careful calculation. I have devoted a great deal of time to this subject, have made very careful measurements, and many calculations by all of these methods, and I have rather come to feel that I would trust

my calculations as closely as observations made by ordinary commercial methods and instruments.

Alexander Gray: My experience has been that the method suggested by Mr. Field is by far the best method. I also think we should carry out his suggestions and guarantee regulation on zero power factor, then we have something which we can test. If we desire a simple method by which to check regulation, then let us use the pessimistic method proposed by Mr. Behrend, and forget about the optimistic method altogether. The majority of alternators have a full load saturation curve on zero power factor very close to the pessimistic curve. I have seen a few machines of which the full load, zero power factor saturation curve was below the pessimistic curve due to the enormous increase of field leakage which we have under these conditions.

Comfort A. Adams: The curve calculations I referred to took account of increased field leakage.

Frank T. Leilich: Messrs. Mortensen and Field in their papers on alternator regulation have called attention to a part of the standardization rules that has long needed revision. The late Professor Henry Rowland once remarked, when told that practise did not agree with theory, "So much the worse for the practise." This is the case with the present Standardization Rules regarding the predetermination of regulation; the practise is wrong from a theoretical standpoint and as consequence the practise gives very poor results.

Mr. Mortensen calls attention to the fact that regulation has been ably handled in a number of papers presented before the Institute and methods proposed for its predetermination which give results in good accord with actual test. Professor Arnold in his celebrated works on design has also given the subject excellent treatment.

The methods which give the best results have in general been open to the criticism that they are rather long and laborious. To get a clear understanding of the principles underlying a rational method of calculating regulation it may be well to outline the factors which cause the voltage of an alternator to fall, when a load is put on the machine. These are:

A. Armature resistance.
B. Armature reactance.
C. Armature demagnetizing action.
D. Increased leakage.

The effect of resistance in causing voltage drop is usually quite small and, as pointed out by Mr. Field, can in most cases be neglected.

Armature reactance, on the contrary, has a pronounced effect on the voltage regulation and must be considered. Messrs. Hobart and Punga in their paper before the Institute (Vol. 32—1904) give a method of estimating reactance. Professor Arnold also derives formulas for this factor. In fact, reactance may be calculated from the design data of the machine with a

very fair degree of accuracy. When the machine is on the test floor, why not determine the reactance by direct measurement? This can readily be done by the application of a voltage of the same frequency as the machine is designed for, and measuring the voltage drop across the armature. As is well known, the reactance will vary with the position of the armature bands with respect to the poles and also with the saturation of the iron in the neighborhood of these bands. However, full-load conditions are the ones usually considered and these may be reproduced with sufficient accuracy for reactance measurements by fully exciting the field and having the current in the armature at full-load value.

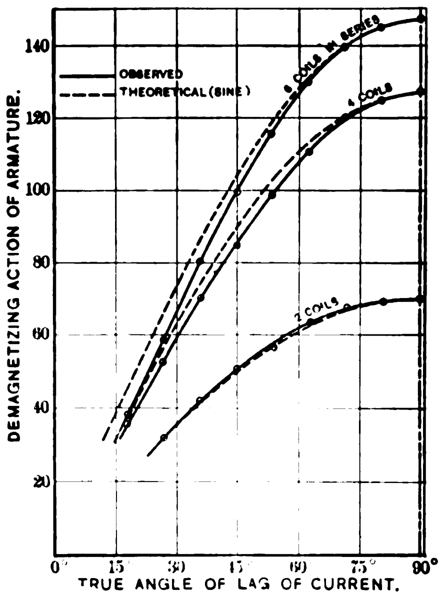

Fig. 8—Armature Demagnetizing Action

Under this condition the machine corresponds to a synchronous motor that has fallen out of step and come to a standstill, the armature current being hunted, however, to normal value. Under the above conditions the armature may be jacked around through 180 electrical degrees and the maximum and minimum voltage drops observed. According to experiments, the average reactance may be figured with sufficient accuracy for practical purposes by using the average of the maximum and minimum drops for calculating the impedance, and, from the known value of armature resistance, figuring the reactance.

The sine formula as given by Mr. Mortensen for calculating the armature demagnetizing action will give remarkably close results.

This bucking action of the armature is the principal factor acting to cause a fall in voltage of a generator and it is essential that it be determined as accurately as possible. The curves in Fig. 8 are the results of some experiments performed by Professor Seyfert and the writer, at Lehigh University, to see how close the demagnetizing action as calculated by the formula agrees with actual results. The machine tested was a salient pole revolving field generator so arranged that the number of the coils per phase could be changed at will. The full line curves are the test results and the dotted curves are sine curves. The curves show that the width of the band of conductors has a slight influence on the demagnetizing action but on the whole the agreement with the sine law is very close.

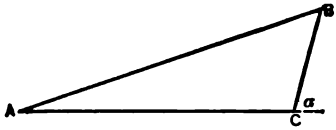

FIG. 9

A B—Ampere turns for full load current at O P. F.
C B—Ampere turns for full load impedance drop.
A C—Armature demagnetizing ampere turns at 0 power factor.
a—An angle of which the cosine is equal to the ratio of the armature resistance to impedance.

Mr. Field has given a method of correcting for the increased leakage under load so that now all quantities affecting regulation may be considered mathematically.

Demagnetizing action as determined from short-circuit conditions is not a true measure of its effect under normal conditions of operation. Referring to Fig. 10, it is clear that a reduction in field strength on the straight part of the saturation curve produces a greater fall in voltage than the same reduction beyond the knee of the curve. However, an assumption that the effects are the same will tend to compensate for the effects of increased leakage, which may then be neglected for most practical calculations.

In conclusion, the following modification of the methods proposed for determining regulation is suggested. With the machine on the test floor make the following tests:

1. Armature resistance.
2. Armature impedance, from which reactance may easily be calculated.
3. No-load saturation curve.
4. Field ampere-turns for full-load current at zero power factor.

Having the above, the armature demagnetizing ampere turns for full load current at zero power factor may be calculated graphically as shown in Fig. 9. Lay off, Fig. 10, the line E_t equal in length to the terminal voltage of the machine at an angle with OX such that the cosine of this angle is equal to the power factor. Draw AB the RI drop, if this is to be considered, parallel to OX. From B draw BC perpendicular to OU and of a length representing the reactance drop. Then OC is the internal voltage of the machine and θ' the total angle of lag.

From the figure it is evident that *OD* represents the ampere-turns that would be required if demagnetizing action were not present. Step off *OE* on *OC*, equal to the demagnetizing ampere-turns of the armature at full load current zero power factor, to the same scale as the field ampere-turns. Then *OF* represents the armature demagnetization under the given conditions. From *D* step off *DG* equal to *OF*, then *OG* represents the total ampere-turns re-

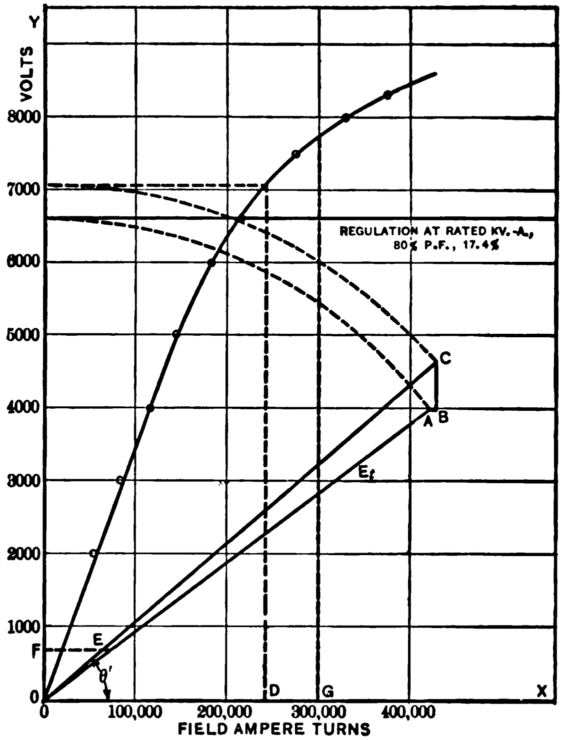

FIG. 10—3600 KV-A. GENERATOR 6600-VOLT THREE-PHASE, 60 CYCLES, 225 REV. PER MIN.

quired for normal load under the given conditions. The intersection with the no-load saturation curve of a vertical line drawn through *G* gives the value to which the voltage will rise if the load is removed.

This method has been found to give results close to actual test. Inasmuch as all of the quantities admit of predetermination the calculations may be made from design as well as test data.

W. L. Waters: The Potier triangle method of determining regulation, which is described by Mr. Mortensen, and especially

the empirical method of applying it outlined by Mr. Field, is undoubtedly the most satisfactory method used by designers to-day. But I think it will be well to refer all measurements to a complete zero power factor load saturation curve determined by direct test, rather than to rely too much upon theoretical or empirical deductions. Mr. Field's triangle method requires one zero power factor load reading, and it will require very little more time and expense, and be much more satisfactory, to complete the zero power factor load curve. With this and Mr. Field's recommendation No. 4, we have a reliable basis for checking any regulation guarantee for any power factor from 100 per cent to 0 per cent, and for any current load not greater than the highest value for which the zero power factor curve was determined.

George Smith: The writer can testify to the accuracy as applied to widely different types of alternators of the method proposed in Mr. Mortensen's paper for the calculation of alternator regulation. He would call attention, however, to a method set forth by Professor C. A. Adams in the ***Harvard Engineering Journal*** in 1902- which is based on the same fundamental principles and is quite as accurate as the method under discussion. Prof. Adams' method appeals to the writer as eliminating all graphical construction. With the armature reaction known and with the no-load saturation curve, the short-circuit characteristic and armature resistance taken from test, the regulation for any load at any power factor may be calculated by a few simple formulas.

The armature reactance (x) is determined from the short-circuit test. The field m.m.f. at short circuit is used to overcome the armature reaction and the impedance drop. As the resistance is generally small compared with the reactance, the reactance and the impedance may be assumed to be of the same value. Then the reactance drop, IX, may be read directly from the no-load saturation curve at the field strength.

$$F_x = F_s - A$$

where F_s = field ampere-turns giving the current I at short circuit,

and A = the armature reaction at the current I.

With the reactance, X, thus determined and the resistance, R taken from test the virtual generated voltage, E_v, for any load or power factor may be calculated from

$$E_v = \sqrt{(E \cos \theta + I R)^2 + (E \sin \theta + I X)^2}$$

where E = normal rated voltage
and $\cos \theta$ = power factor of load.

The field strength, F_v, corresponding to E_v is read from the no-load saturation. Then the total field strength, F, required to give the voltage E at the load I is figured from the formula

$$F = \sqrt{\left(F_v + A \frac{E \sin\theta + IX}{E_v}\right)^2 + \left(A \frac{E\cos\theta + IR}{E_v}\right)^2}$$

The no-load voltage, E_0, corresponding to the field strength F is then read from the saturation curve and the regulation determined therefrom.

In the application of the above formulas it is to be remembered that the values of voltage, current, resistance and reactance are per phase of the armature windings.

C. J. Fechheimer (by letter): The methods which the authors propose for the determination of the zero power factor curve, from which the curves at other power factors may be determined with sufficient accuracy for any commercial purposes by means of Kapp's diagram, are in general those which are the results of experience and have been found to agree very closely with experimental results.

We wish only to suggest a method for enabling the purchaser or his representative to determine what the inherent regulation of his machine is, without resorting to the test and calculated no-load saturation curve with full load leakage advocated by Mr. Field, nor to the indeterminate proportions of the triangle of Mr. Mortensen.

We have found from considerable experimentation that the reactance component of the triangle used by both authors can be determined by direct measurement with the rotor removed, the current being circulated at normal frequency in one phase. The voltage then measured will be very close to the reactance drop in the machine with the same current. In order to allow for the armature reaction we can determine this from the short circuit curve, after allowing for the reactance drop, and determining how many ampere-turns remain. These ampere-turns, however, should be increased in the case of a machine in which the magnetic circuit contains iron which is to some extent saturated, by increasing these ampere-turns by an amount equal to the leakage factor.

In general this factor is 1.1 to 1.3 and sufficiently accurate results could in general be obtained by assuming it to be 1.2 for the Institute rule. This in general gives results which are but very little different from those obtained by actual test at zero power factor.

Chairman Kennelly: I will call on Mr. Lamme to make a summation of the conclusions arrived at thus far in this conference, in his opinion.

B. G. Lamme: It is difficult to state what conclusions can be reached, as a result of the discussions, because we have not

gotten all the evidence together. However, I can make a few definite statements.

When we first took up this question of the revision of the rules, the two sub-committees got together and decided upon certain lines upon which to work, and then later the Sub-committee on Revision took up many of the points which have been discussed in the papers presented at this meeting. One thing, evident all the way through, was that a great many desired rules could not be defined accurately. We could not measure temperature accurately. We could not specify how to make equivalent load tests, and we even could not say how to measure the losses accurately. Apparently, nothing could be done accurately, and yet there has been a general impression that what we have been doing in the past was all right.

So many changes were suggested that it was decided that rather than go ahead and make changes ourselves, we would put the whole matter before the public, present the evidence, and acknowledge that we could not do anything accurately and then find what others thought. It was suggested time and again that we would bring a tempest about our ears, and we have done so to some extent, but we decided that it was better to bring out the facts, and then, if we could not draw any conclusions from an open discussion, we would go ahead as best we could.

From the discussion it appears to be accepted that we cannot obtain accurate results, but in some cases, it seems to me, an exaggerated impression of the inaccuracies has been obtained. Take, for instance, the question of load losses. From the discussion, one might assume that these are very large in many cases. I think one of the reasons why it was thought that the load loss in alternators is excessive is because, in many cases, it was referred to as a percentage of the armature copper losses on short circuit, and this percentage looked rather large. But it must be remembered that the armature copper loss is sometimes relatively small, so that an extra loss of 100 per cent on short circuit may be a very small item in the total losses. It may sound large as a percentage, but the total amount may not be very noticeable.

Take a large turbo-generator, for instance; the copper losses in the armature may be only 20 per cent as great as the iron loss and may be also only 20 per cent as great in the friction and windage, or in effect the copper loss may be only 10 per cent of the other losses, or less than 10 per cent of the total losses. In such cases, it makes but little difference if the armature copper loss is increased 50 per cent, or 100 per cent, since it represents but a small part of the total. Upon analysis, it will be seen that, in general, most of the extra or stray losses are quite small in proportion to the total losses in the machines.

It is the same way with many other things. We must not get an exaggerated idea of the value of the inaccuracies or discrepancies. In most cases, it is possible to get a fair indication

of them. That is what we have been trying to do, in bringing them out in this convention. The fact that we cannot make accurate measurements in many cases, is, from one point of view, rather discouraging. On the other hand, we might say that it is very encouraging to have these facts so fully recognized, for if we cannot make accurate determinations, it is better for everybody to know it, which has not been the case heretofore. It is better to know that we cannot make accurate determinations than to think we can and be wrong about it.

We must consider that while the facts brought out show how indefinite is our understanding of some of the laws with which we are working, yet our admission of ignorance does not really make the application of these laws any more inaccurate than heretofore, and does not make our errors any larger than they were, and it was thought by the Standards Committee that, in bringing these facts forward, we would be conferring a benefit on the industry by showing just what the true situation is.

Heretofore, there has been a general air of confidence concerning many of these things. Until comparatively recently, many of the now questionable points were considered as entirely satisfactory. Electrical designs are now better than ever before, but we now recognize many of the real difficulties, and do not hesitate to tell about them.

Leo Schuler: I wish to congratulate the American Institute of Electrical Engineers and especially the Standards Committee, on this very successful convention, and I must confess that I have learned a great deal, not only from the papers and discussions presented, but also by the general manner in which this Convention was organized and its transactions carried on. I was quite surprised to see how many of your engineers took an active interest in the Standardization Rules, and I shall bring this as a brilliant example before the eyes of my German colleagues.

I wish to thank you, gentlemen, for having not only allowed me to attend your convention, but to take active part in the discussion. I feel sure that the report I am going to make to the German Standards Committee will help us a good deal in the successful completion of our work, and I also hope that the remarks I have occasionally made here will somewhat contribute to make the American and the German Standardization Rules, if not equal, at least comparable.

If you will consider that the world's market of electrical machinery is practically controlled by the American and the German firms, you will understand the importance of such an agreement in the Standardization Rules. I thank you, gentlemen, for the very kind reception you have given me.

DISCUSSION ON "2400-VOLT RAILWAY ELECTRIFICATION" (HOBART) AND "TRUNK LINE ELECTRIFICATION" (KAHLER). NEW YORK, MAY 20, 1913. (SEE PROCEEDINGS FOR MAY, 1913.)

(Subject to final revision for the Transactions.)

A. H. Armstrong: The two papers presented before the Institute at this meeting arrived at the same happy conclusion as to the benefits to be secured in the electrification of steam roads, but differ as to the means of securing this end. In other words, one paper advocates the single-phase and the other the direct-current motor. Instead, therefore, of following the usual procedure of side-stepping the question of single-phase versus d-c., I will confine my remarks to a broad discussion of this question as affecting the general subject of electrification.

We seem to be entering an era of electrification of steam roads, and perhaps the enthusiast for single-phase alternating trolley operating at high potential may be unduly influenced in drawing his conclusions by reason of the small tonnage carried on some of the lines where electrification is proposed. A high-voltage trolley means a minimum expense for copper and substations, but an increased cost of motive power. Looking at the matter broadly and considering that the investments made today should be based upon taking care of the traffic of to-morrow, it is reasonable to figure the first cost of electrification of any given road on the basis of an increase of 50 per cent or 100 per cent over the present tonnage now carried.

It is a well known fact that the cost of locomotives equipped with single-phase a-c. motors is higher than that of a locomotive equipped with direct current motors capable of doing similar work. When the total expense for motive power is small, that is, when the road is carrying a small tonnage and trains are infrequent, the high cost of locomotives does not become burdensome, but with increase in traffic continually demanding larger investment in motive power, the handicap of the single-phase motor is more keenly felt and may soon over balance the apparent initial saving in feeder copper and substation expense required with the use of the direct current motor. On the other hand the substation and line copper expense is more or less proportional to the tonnage and speed of the moving train and is seldom influenced by the frequency of this train service. In other words, the capital invested in substation and feeder copper to take care of the movement of ten 2500-ton trains per day is generally great enough to permit the movement of twenty trains per day of equal tonnage. The feeder copper and substation installation therefore constitutes more or less of a fixed capital investment subject to a slight increase with increase in tonnage, while the locomotive investment increases with the tonnage or even faster when track congestion commences to be a factor. We are quite liable therefore to turn the apparent saving of to-day into an increasing burden of expense in the future with the increase in tonnage which may be expected on our trunk lines. Should the selec-

tion of the single-phase system be based upon the apparent saving in first cost with present tonnage, the same reason may not hold if based upon the same road carrying double the tonnage. In other words, in balancing substation and feeder copper expense against locomotive expense we are comparing what is more or less of a fixed investment against one that will increase in due proportion to future increased tonnage.

The company with which I am associated, in common with other investigators, has been for several years developing a piece of apparatus known as the mercury vapor rectifier, and the successful development of this rectifier will open up increased possibilities which we hope will accelerate the electrification movement. When developed, the rectifier affords the most efficient means known of changing from alternating to direct current. The glass tube of 10 or 15 kw. has expanded into a steel rectifier of over 1000 kw. as it stands developed to-day, and no immediate limits are in sight as to the ultimate capacity of this piece of apparatus. While the rectifier is still in the laboratory stage so far as its actual commercial use is concerned, it holds promise of being available in the immediate future and its success will have a bearing upon the electrification work of the future.

There are two methods of using the rectifier.

First, it can be placed upon a locomotive equipped with direct-current motors and transformer used in connection with 11,000-volt single-phase trolley distribution system. In this case the rectifier will operate single-phase, will produce a current that is uni-directional, but the pulsating character of the current may demand special construction of the d-c. motors. The single-phase step-down transformer will also be special in character in order to provide for the needs of the rectifier.

In general the advantage offered by the use of the rectifier on the locomotive lies in the possibility of using direct-current motors instead of single-phase, and thus obtaining the admittedly better constants of that type of motive power. I know no authority who will question the superiority of the direct-current motor over the single-phase a-c. motor as applied to traction work, and the rectifier placed upon the locomotive itself combines the good qualities of the d-c. motor on the locomotive with all those advantages claimed for the single-phase high-tension trolley distribution.

Second, the rectifier may be placed in substations located at the most desirable point along the right of way. In this case the rectifier will use balanced three-phase energy of any frequency, taking energy equally from all three legs of the circuit, and by using a multi-phase rectifier it will result in giving direct current in which the fluctuations are largely eliminated. This will enable such a rectifier substation to feed standard direct-current motors and will moreover provide a balanced three-phase load which can be supplied from existing transmission

systems at any frequency without causing undesirable interference with lighting and miscellaneous load distribution. The general advantage of locating the rectifier in the substation is that its efficiency will probably be from 10 to 15 per cent higher than that of a motor generator set, and furthermore the rectifier is adapted to deliver direct-current energy of any potential required and is therefore admirably fitted to supply 2400 volts or higher to the trolley. Furthermore, the substation being without moving machinery, can be operated with a minimum of attendance and may show an attractive reduction in first cost over motor-generator set substations.

Introducing the rectifier substation upsets our pre-conceived ideas as to the proper relation of cost of substation and feeder copper, as the rectifier substation shows a very marked increase in efficiency, decreased cost of complete substation, and we may even anticipate the time when it can be operated without attendants in such localities as would require no attendance with a a step-down transformer station. The success of the rectifier therefore means just as much to the high-voltage direct-current motor system as to the single-phase trolley.

In conclusion, it seems to me that looking at the matter broadly and without enthusiasm but with full knowledge of the operating facts of to-day and the possibility of the immediate future that the single-phase commutating motor as such is destined to become more or less a thing of the past. It is even a grave question whether the single-phase trolley locomotive of any description with its interference with neighboring telephone and telegraph lines, the difficulty and expense of providing single-phase current without erecting a generating and distributing system devoted solely to railway apparatus, and with the high first cost and cost of maintaining the motive power, do not all together present difficulties which make the single-phase trolley system undesirable viewed from the standpoint of the high-voltage direct-current motor and its possibilities.

While the Butte, Anaconda & Pacific direct-current locomotive was designed and is now in commercial operation at 2400 volts, the company constructing it also built and tested high-potential direct-current apparatus up to 5000 volts with entire success, and no objection can be raised as to the practicability of using this high potential if local conditions demand it.

As a final remark I wish to state that as evidence of the possibility of having the mercury rectifier available in the near future, there was run at Schenectady during the past week a test with one of the Butte, Anaconda & Pacific 80-ton locomotives and a 1000-kw. mercury vapor rectifier, during which test no restrictions whatever were placed upon the motor output, such as operating at full load, slipping the wheels, etc. It is probable that within a few months there will be equipped for demonstration both a locomotive and a stationary substation containing mercury rectifiers which will be put into commercial

operation to secure the active experience needed to make this type of apparatus commercially available.

F. E. Wynne: In going over Mr. Kahler's paper I noted his tables on the division of time for steam and electric locomotives, Tables 9 and 10, and thought it would be useful to plot these (Figs. 1 and 2) so as to show at a glance what might be not apparent in these tables without study. The values for steam are actual results, and those for electric locomotives are Mr. Kahler's estimates.

The top section in each figure represents the time on the road; the bottom section represents the time spent in the engine house. It is interesting to note that for the passenger locomotives these sections are approximately reversed for electric and steam operation. On the freight engine the difference is not so great, although the electric engine makes considerable gain over the steam. In the freight diagram there is a certain area representing the time spent in sidings; in other words, the locomotives are ready for operation but are not in actual motion on the road.

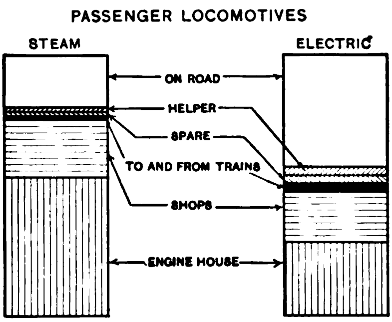

FIG. 1

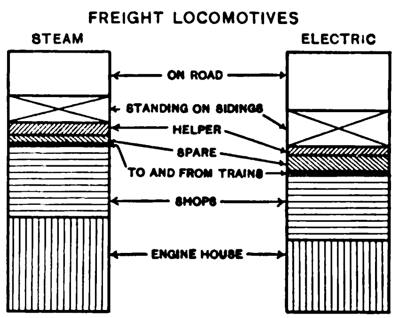

FIG. 2

Mr. Kahler has used an electric locomotive of much greater hauling capacity than his steam engine. The steam engine weighs a total of 185.1 tons with loaded tender, and has a maximum tractive effort of 43,000 lb. The electric locomotive weighs 110 tons, all weight on drivers, and has a maximum tractive effort of 55,000 lb. Applying these tractive efforts to show what can be done on short ruling grades, I have worked out Fig. 3, for grades from level to a maximum of 4 per cent showing the ratio between the maximum tonnages which the electric and steam locomotives can haul. On level track the electric engine hauls 38 per cent more than the steam engine, and on a one per cent grade approximately 50 per cent more. Grades up to 4 per cent are shown because such grades occur on branches of existing steam roads. Fig. 3 is based on train friction of 6 lb. per ton for trailing load, 15 lb. per ton for the electric locomotive and 25 lb. per ton for the steam engine.

Mr. Kahler's paper refers to gasoline motor cars and gasoline-electric motor cars. In this connection I think it is well for us to remember that most of the comparisons which have been made between steam locomotive operation costs and the costs of these self-contained motor cars have considered everything in figuring out the cost with steam, while in giving the cost of the self-propelled units nothing is included for track maintenance, signalling, despatching, or general expenses. So the comparison is not always a fair one.

I was very much interested in the table in which Mr. Kahler shows the limiting grades for both electric and steam operation, and where he shows the tonnage which can be handled in the various districts with each type of engine.

I think the chief value to be found in Mr. Kahler's paper, aside from the actual records of steam operation which he has submitted, is the fact that he has shown the way to attack the problem of ascertaining whether it will pay to electrify a steam road; he has shown how to analyze steam operation and estimate the probable saving by electric operation. His results are very interesting, showing, for electric operation, an annual saving of $940,000.00, on a net investment of approximately $8,000,000.00 or a gross investment of approximately $10,000,000.00. In other words if we take account of the salvage for steam locomotives, the return on the investment is approximately 11½ per cent, or, if the steam locomotives are worn out and there is no salvage at all, we still have 9½ per cent.

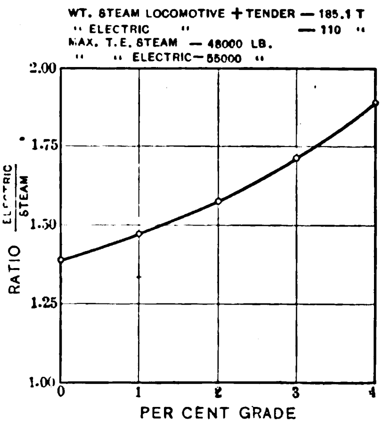

FIG. 3—RELATIVE HAULING CAPACITIES OF ELECTRIC AND STEAM LOCOMOTIVES ON SHORT RULING GRADES

Table 21, page 1086, throws some light on the estimate of locomotive maintenance made by Mr. Hobart. The figures given in table 21 show that maintenance is largely affected by the class of traffic in which the locomotive is used. In high speed traffic, where the mileage is great, the cost per engine mile is lower than with slow speed service. With the exception of those for the helper engine all of the figures given by Mr. Kahler are below 10c. per mile per 100 tons of engine; the passenger engines show between 4c. and 5c. and the freight engines between 6c. and 7c.

In Table 22, a most interesting item is that boiler washout requires 42 per cent of the steam locomotive's engine house expenses.

In connection with Mr. Hobart's paper, I have noticed some things which steam railroad men may see, and, knowing they are somewhat unusual for steam operation, may be led to doubt the value of other figures in the paper.

On page 1021, for a certain class of engine and train, the pounds of coal per drawbar horse power-hour are determined. When converted into other units it shows, on a basis of 14,000-B.t.u. coal, the gross ton-miles hauled are 7.6 for each pound of coal; and, on a basis of 11,000-B.t.u. coal, 6 gross ton-miles for each pound of coal burned. These values, I believe, are rather high, even in passenger service, as I have some records of steam operation which show that this figure for both freight and passenger services is between three and a quarter and four gross ton-miles for each pound of coal burned.

The use of bogey trucks is mentioned for locomotives exceeding 45 miles per hour maximum speed. In this connection it would be of interest to know what is considered the limit of dead weight per axle on these leading trucks.

On page 1023, the writer gives some rather high over-all substation efficiencies; 89 per cent for dense service and 78 per cent for sparse service. These values are high, and if worked out for the usual load factors, with motor generator sets and including the transformers and exciters, these percentages would be decreased from 7 per cent to 10 per cent. Otherwise, it is rather hard to account for some of the large differences between the input and the output of substations on actual roads.

Mr. Hobart informs us that "for a given life of the contact roller, tests reveal the following relation between the speed of a pantagraph trolley and the current which can be collected," that with speeds varying from 10 to 60 miles per hour the roller contact collects from 1200 to 300 amperes, respectively. These figures seem very high, and it would be very interesting to the Institute to know what life of the contact roller can be secured with a roller collecting these currents at these speeds, as the roller is somewhat expensive to renew.

The paper contains an apparent inconsistency in that 34,000 lb. is taken as the drawbar pull for two of these Butte, Anaconda & Pacific locomotives, and the corresponding speed is taken at 14 miles per hour. On the next page the continuous tractive effort is given as 25,000 lb. each, or a total of 50,000 lb., at 15 miles per hour. Evidently this speed of only 14 miles per hour at 34,000 lb. drawbar pull takes account of the large line drop that goes with a direct-current installation. On the other hand, when it comes to estimating the current to be collected, 2400 volts at the locomotive is the assumed voltage.

If the speed curve of this particular locomotive were available, I think we should find a somewhat larger current to be collected at a somewhat higher speed.

The gross-ton-miles per ton of coal burned are given as 3.1, which is in line with the information we have.

Reference is made to 44 miles per day, average for 365 days, as being a high figure for Mallet locomotives. Some records of Mallets in mountain service averaged over periods of one year or more show a minimum of 48 miles, and a maximum of 75 miles, per day, and I do not think 44 miles is an exceedingly high figure, particularly as the higher figure includes for each locomotive at least one month out of service for general overhauling.

In connection with the 96 mile electrification of a mountain grade, I think too many electric locomotives are assumed; that is, 48 double-unit engines, when the maximum number of trains on the line is 28, as shown in the foot-note, page 1044.

The paper states that on a basis of 8 lb. per ton train friction, and a grade of 2.2 per cent, the draw-bar pull is found to be 94,000. This is, then, arbitrarily increased 36 per cent to allow for bad weather conditions. Of course, the effect of grade is the same in all kinds of weather, therefore, the result of making this increase of 36 per cent in draw-bar pull is that the friction is run up to 26.7 lb. per ton, which is very high, even for bad weather. If we use these figures, we find that the engine, with 128,000 lb. drawbar pull, for 1800 tons trailing in bad weather, will handle 2560 tons trailing load in good weather. Thus, the tonnage rating for bad weather is only 70 per cent of the good weather rating. This difference is much greater than that in common use on steam railroads.

Another indication that the total number of electric locomotives is very high is that the average works out only 75 locomotive-miles per day, per electric engine.

The paper gives some indications of the permanent investment to which Mr. Armstrong referred. Taking the cost of overhead and substations, and assuming the substations are on a basis of 200 per cent overload for short periods, it works out to $37.00 per kw. for substations and an overhead feeder system of 2,000,000 circular mils of copper in addition to the trolley. These figures seem high for permanent investment; for that reason I do not think 2400 volts d-c. is most suitable for heavy traffic. As it stands, 2400 volts is not sufficiently high; it may be fit for certain traffic, but for heavy traffic it is certainly too low.

Referring again to the matter of train resistance, we read that in descending " the power required for propulsion will be negligible for most of the descent, nevertheless, steam must be maintained in the boilers, and also, owing to the high frictional resistance of the Mallet engines, power will be required for all grades materially lower than the average value of 1.5 per cent." If we work this out for a 250-ton Mallet engine, with trailing load of 600 tons pushing it down hill, we obtain a result which looks rather high; that is, 80 lb. per ton frictional resistance for the Mallet.

The comparison is made on the basis of different amounts of

traffic for steam and electric operation. I think it should have been worked out to handle the same traffic in which case the electric locomotive would have made a better showing.

Referring to page 1055, I ask if "the correct basis for estimating the commercial results to accrue from the electrical operation is to compare all those items which are affected by the use of electricity instead of steam," why is it that this is "inconsistent with the retention of the forms which have become customary in analyzing the results of steam operation"? It seems to me that is really the good way to get at the answer, rather than the inconsistent way.

In connection with Mr. Armstrong's remarks as to increase in traffic not materially affecting substation or feeder cost, I would like to call attention to some installations made in the past, where the substation and feeder costs have been materially increased when the traffic was increased. The Pittsburgh, Harmony, Butler & New Castle Railway, at 1200 volts d-c., was one case. Another was the 600-volt d-c. electrification of the West Jersey & Seashore Railroad.

George Hill: I have been impressed while sitting here listening to these two papers and the discussion of them, and from my own acquaintance with the trend of railway electrification, with the fact that railway men throughout the country are taking a greater and greater interest all the time in the electrification of steam roads.

In these days of ever-increasing effort toward high efficiency, and the desire to get the best and most out of everything that is done, it is gratifying to the electrical engineer to see the steam railroads turning more and more to the use of electrical power. It is especially gratifying to see that this is being done largely in a consistent and logical manner. That is, the roads which are adopting electrification, especially in connection with the handling of freight, are doing it by applying the electrification remedy to those points where it is most needed; I refer particularly to heavy grade work. I may mention at this time an example of this in the electrification of the Norfolk & Western Railway, the mountain grade division called the Elk Horn grade, between Bluefields and Vivian, in West Virginia. It is generally known that this electrification is in progress, and it is one of the cases where it has been found that a very material saving and a very satisfactory return on the investment will be effected by electrification. Our firm has had occasion to investigate and report on a number of electrification propositions of this general character, and it is evident that for many cases of this heavy mountain-grade character, electrification will make a very satisfactory showing, not only in the savings under equal conditions, but also by greatly increasing the capacity by increasing the speed and improving the reliability of the service, and thus the earning power of the property.

W. S. Murray: I realize that it is necessary for me to cut my remarks short, and this has been made possible by most of the wind having been taken out of my sails by the very excellent line of inquiries which have been asked by Mr. Wynne with regard to Mr. Hobart's paper.

I was very curious indeed about some of the statements in that paper, and doubtless the answers to Mr. Wynne's questions will bring the information I most desire.

There is one thing I want to try to emphasize that has struck me forcibly in the matter of electrification, and that is this: Electricity is nothing more than an agent to do the same work that steam has been doing for about 80 years, and in settling these problems of electrification, both with reference to level and grade conditions, it seems to me the first thing we electrical engineers owe to our railroads in this country before we begin to electrify them is to see if they have been reduced to the best steam basis.

1. We have been prone to base our opinions and our conclusions on electrical figures that have not got for themselves the same basis that steam has. Therefore, to repeat, we must get the territory to be considered upon a proper steam basis before we take up the matter of its electrification. Now, as the railroads have grown in age, so have the efficiencies gone down. Certain local conditions and matters that appertained to the relation of traffic and equipment schedule have not been caught up as they should have been; and so when we electrical engineers go into them, we set up first our wonderful schedules, and show the electrical economies above steam, and capitalize the project on a basis that takes care of the construction bonds, indicating a magnificent dividend on the electrical investment. Now, that has been the tendency and I think that we should be extremely careful to avoid such practises.

Now I want to draw attention to the fact that a steam locomotive can, if the fireman's arm holds out, develop its maximum tractive effort continuously. That is a very important point.

2. An electrical engine has no fireman's arm between it and its tractive effort, but it has in its place a temperature rise which must be reckoned with.

3. The electrical engine has the advantage of the steam engine for sustained horse power; but the steam engine has the advantage of the electrical for sustained tractive effort, ex. fireman's arm.

It is within the realm of possibility that steam locomotives are to be of a different order in the future than they have been in the past. Oil burning and automatic stoker locomotives will make us electrical engineers hustle to prove our case.

The electrical engineer who has a clear-cut understanding of the foregoing facts, knows their value, and so I can only draw your attention to Mr. Wynne's figures. He shows an interesting

line of ratios in regard to steam and electrical engines on different orders of grades. The most important part of Mr. Wynne's diagram is not shown, and that is the length of grade involved. These papers which we have been much interested in tonight. are of an academic order; the real physical conditions of the problem are not sufficiently discussed.

There are many figures which Mr. Kahler has brought out which are most interesting and absolutely true; and yet the real question is their proper correlation and application to the specific problem in mind.

I want to extend a warm arm of friendship to my friend, Mr. Armstrong, who has joined me on the single-phase bandwagon.

The power houses of the single-phase and direct-current systems are about a stand-off. The direct-current locomotives cost less than single-phase locomotives, but the distribution system for the single-phase system is by far the more economical of the two. Now you see this interesting combination where we secure a minimum cost of power station, minimum cost of distribution and finally the minimum cost of locomotive. Mr. Armstrong has indeed built a beautiful bridge, over which I am very glad to walk and meet him half-way. As I have always had to admit that the cost of single-phase locomotives was more than that of direct-current locomotives, since from the time they have been manufactured they have necessarily been heavier, I have been as forcefully required to admit that the distribution system for the single-phase system possessed such inherent characteristics of economy as to far offset the greater cost of the a-c. locomotive, and if single-phase current for heavy trunk line traffic has now been accepted as the economic form for electric train propulsion my position would be truly illogical not to welcome with Mr. Armstrong the coming of the rectifier locomotive, which will bring out still more its economic characteristics. In the absence of the rectifier the single-phase motor was a necessity to make use of the economical single-phase distribution. In the last analysis of the true economics of any heavy trunk line electrification project it will be found that the single-phase motor rules out its direct current brother. The direct current motor has put up a good but a losing fight for its position in this field, and through the medium of the rectifier let us hope that it regains its former position. I am interested in the type of motor only in as far as what position it may take in the consideration of the electrification as a whole. Because the direct-current motor may replace the single-phase motor through the medium of the rectifier, this but stamps the electrification all the more single-phase, for the reason that the distribution system has made that end possible.

A. H. Babcock (by letter): The two papers by Hobart and Kahler dealing with trunk line electrification merely serve to emphasize a conviction that has been growing steadily in my mind for some years, that generalization with reference to

trunk line electrification is extremely dangerous. In hypothetical cases, or even in cases where only a preliminary estimate is required, often curious results are reached by the use of improper bases on which to form the arguments leading to conclusions. The incorrect premises may be due to a partial study of the case involved or a desire to make a very favorable showing in order that capital may be interested to investigate farther, or to a variety of causes, but the result is the same; while in the hypothetical case, from a given set of assumptions one may argue himself into almost any desired position, in practise the hard and unyielding physical facts are met.

During the last ten years my office has made reports on every mountain railway exit from the Central California valleys, and on other mountain districts in other parts of the West Coast country. Often these reports have been the result of agitation on the part of power companies with a surplus of power for sale. In other cases they have been the results of pressure exerted by the manufacturers on the executives of the railway companies. In not a single one of the reports that have been made in considerable number, as stated, could it be said "that the operating economies, which have been effected by superseding with electric locomotives, the steam locomotives on such railways, are enormous and are indeed of such amounts as to defray in a very few years the initial outlays for substations, for feeders and contact-conductors, and for electric locomotives," (Hobart). Quite the converse is the fact and in every case on which a report has been made the conclusions have been adverse to electrification on precisely the reverse of the facts in the quotation above cited.

Whenever the request for such reports has been started by a power company, statements relative to "the very low cost at which the large hydroelectric supply companies in the West can profitably sell electricity," (Hobart), have been made by officials of the power companies; but it is a significant fact that when the same power companies have been confronted with the physical facts of the railway company's requirements as to quantity of energy, maximum demands for power, and load factor, invariably the rates quoted have been quite prohibitive, notwithstanding the fact that usually they are lower than that assumed by the authors of these papers, (Hobart, page 1048 and Kahler, page 1092). As a matter of fact with fuel oil on the West Coast at ordinary market rates, say 70 to 80 cents a barrel, an energy rate greater than 5 mills is utterly prohibitive, as far as water power purchase is concerned; moreover, the annual load factor, although it "should not get lower than 60 per cent," (Kahler, page 1092), seldom rises above 20 per cent as a matter of fact, and as a rule the total energy charge can be wiped out of the annual statement without making a material difference in the conclusions, so small a part does it play in the annual operating cost when the fixed charges and other elements of operating expense are taken properly into account.

Not one of the projects that have come under my notice conforms in the slightest to the following—" But when it is understood that these Western hydroelectric companies already have enormous loads connected to their systems, it will be seen that the fluctuations of a couple of thousand kilowatts more or less imposed by the intermittent operations of a few freight trains is not a factor of consequence" (Hobart, page 1030). Our freight trains require from 4000 to 4500 kilowatts apiece and thus far no power company on the West Coast, however, large its service may be, has yet been found to view with equanimity the possibilities of a number of such loads being thrown instantly on or off its systems; furthermore, the above power demands are of such duration that the figures given represent the continuous capacity of locomotives per train.

The fact that so many men engaged in the study of these problems discuss them from the standpoints of the authors of the two papers from which quotations have been taken, indicates, of course, that in other parts of the country the extremely severe conditions of the West Coast mountain railroading do not obtain. It is obvious also that were I, whose experience in such estimating has been confined exclusively to West Coast work, to attempt to generalize from that experience and the information gained in the study of these projects, the result, if expressed publicly, might be, to say the least, embarrassing to me and amusing to some of the eminent gentlemen who have favored the Institute with general discussions in the past. Precisely this difficulty has been met in discussing West Coast problems personally with Eastern factory engineers, and it was not until these same engineers came West and investigated on the ground for themselves that a mutual understanding of each others' words was reached. With this thought in mind the foregoing remarks are submitted, not at all in criticism of the papers referred to but as supplementary thereto.

H. Y. Hall and G. W. Welsh (by letter): Mr. Kahler's paper states that only ten electric locomotives would be needed for the through passenger trains; this on a 468-mile line with three engine districts and three through passenger trains each way per day. Assuming that it is the intention to operate the 468 mile line electrically with three engine districts, as indicated by the paper, an examination of the train sheet shown in Fig. 2, for the through passenger trains shows that there are actually required for the operation of three through trains each way per day, 3 locomotives on engine district No. 1, four on district No. 2, and three on district No. 3, or a total of ten locomotives actually required, assuming all trains to be on time and no extra trains. This does not include any locomotives " in shops, spares, in engine house, running to and from trains, and in helper service." The time saved in taking water mentioned is small for passenger service and for the above train sheet will not reduce the number of electric locomotives required for actual

service. On most western railroads during the heavy tourist season, it is practically an every day occurrence to run passenger trains in sections; and on days of extremely heavy tourist travel, the number of trains is often increased by 40 to 50 per cent. Judging by the figures given in Table VI, it is evident that Mr. Kahler does not consider that more than one section of any train will ever be necessary. In this respect the road considered by the author is unique, since it is the only road in the western part of the United States which can run without extra trains. It would seem that an allowance of twenty passenger locomotives, instead of ten, would not be excessive on both the grounds of reliability and actual traffic.

Referring again to Table VI, under "Freight Trains," the ratio of maximum day to average day appears to be exceedingly low. On some of the through lines in California, it is not unusual during the heavy fruit shipping season to have a maximum day of 2 to 2½ times the average day throughout the year. Evidently, the number of locomotives must be sufficient to take care of the maximum day. In steam operation, on a large system, the usual way of taking care of this excess traffic is to rush all available locomotives from other parts of the system to help out the congested district. This is not possible with electric operation unless the entire system is operated electrically. Another point is that freight trains very seldom run on time and although they may be dispatched at stated intervals from one terminal, they rarely reach the other terminal with the same time interval between them. Therefore with the forty-three freight locomotives (that is electric freight locomotives,) shown in Table X, we think the road under consideration by Mr. Kahler would find itself frequently with its cars at one end of the line and its locomotives at the other. Of course, in times of emergency, electric locomotives can be run over more than one engine district without injury, but in our opinion the actual requirements of the road under consideration would be more nearly realized if the number of freight locomotives, given in the paper were increased by 50 per cent, or say to 60 locomotives.

It should be noted that under "Locomotive Repairs," the cost per locomotive mile given for single-phase locomotives is based on the published reports of two roads operating direct-current apparatus. It would be interesting to know what is the repair cost per mile on single-phase locomotives, but only one road in the United States operates a sufficient number of these equipments to give reliable information and to the best of our knowledge this has never been published.

The "Estimated Cost of Electrification" given is altogether too low to be conservative.

It is not possible, for $5000 per mile, to build a double-circuit steel tower transmission line of sufficient factor of safety and with sufficient copper to hold the losses and regulation within the proper limits, especially with low power factor lagging current

as would obtain with a single-phase electrification. This cost should be increased to $6000 per mile.

Judging from the extremely low cost given, the author is not considering the use of catenary construction. For the class of service required, the catenary construction would be none too good. At a Pacific Coast point, located close to the source of supply of good and cheap cedar poles, it costs $2175 per mile (not including engineering and contingency) for single track bracket 1500-volt, d-c. catenary construction. In this case $2500 per mile should be used, on account of higher voltage, generally stronger type of construction for main line operation and to cover installation of feeder.

The double track span construction would cost $4000 instead of $2600 per mile.

The four or more track bridge construction would cost nearer $15,000 than $9,000 per mile.

With the increase in first costs and increase in number of locomotives as given above, the total first costs would be $12,698,209 instead of $9,972,000, while the net estimate would be $10,686,209, instead of $7,960,000.

The total of maintenance of overhead structures and substations, Table XV, is too low to cover necessary emergency gangs, repair gangs, patrolmen, material, etc., for the proper maintenance of a 468-mile section of a single track main line with so dense a traffic. This item should be increased at least 60 per cent.

Referring to Table XVI, Mr. Kahler has based his depreciations upon estimated first costs excluding engineering and contingency. If in making estimates for immediate work it is necessary or desirable to add a contingency to cover fluctuations of material costs and unforseen items or difficulties, it is certainly necessary to add a contingency for work to be done 20 or 30 years after making of an estimate. It is common knowledge that to do certain classes of work, it now costs three times as much as it did 20 years ago. Then again, it would not be desirable to do the work in the same manner twenty years hence, so it will be necessary to again pay for engineering. Including the engineering and contingency would increase the depreciation 15.5 per cent. A life of 15 years on poles and fixtures (item 18), would be nearer the accepted value than 20 years, as given, so the depreciation should be $6\frac{2}{3}$ per cent instead of 5 per cent. With the increased first costs, the inclusion of engineering and contingency and increase in depreciation rate on "poles and fixtures," the total depreciation of overhead structures and substations would be $226,046 instead of $144,084.

The total of depreciation of electric equipment, Table XVIII, with increased number of locomotives, as noted above, and with engineering and contingency included in the cost upon depreciation, would be $107,115, instead of $64,740.

With the increases given above, the total cost of electric

operation (Table XX) would be $3,090,178, instead of $2,908,409 and the annual saving would become $758,231 instead of $940,000. This would give a net return of 6.8 per cent, which with interest of 5 per cent, would give a net profit of 1.8 per cent on the investment, which is too small a profit upon which to base a recommendation for electrification, as this estimated profit would be entirely wiped out if the "actual" expenses of electric operation were 7 per cent higher than the estimated operating expenses.

Mr. Hobart, gives a first cost of $8,500 per mile for overhead contact line, rail bonding and feeder copper. Several paragraphs above he gives the annual efficiency, locomotives to substation as 93 per cent. This would give an efficiency of 91.1 per cent during the heavy traffic period. With a substation spacing of 26 miles and 90-lb. rail, single track, the cost of the positive feeder alone, (excluding trolley) to give efficiency of 90 per cent on maximum day would be $6600. This is based on the use of aluminum at 33 cents per lb. erected, which is equivalent to copper at 15½ cents per lb. erected. This calculation is based upon a minimum condition of only one train at a time between substations, whereas with the speed of trains and interval of starting given, it is possible to have two trains at a time on the up grade between substations. In our opinion to obtain an annual efficiency of 93 per cent, it would be necessary to spend at least $12,000 per mile for overhead contact line (catenary construction), rail bonding and aluminum feeder. It should be borne in mind that on mountain divisions, it is necessary to blast at least 60 per cent of the holes for setting trolley poles.

During the maximum traffic period of 18 1800-ton trains each way per day as given with 12,200 kw-hr. per locomotive journey and the same percentages added as shown on page 1048, the average load per substation will be 6150 kw. instead of 3200 kw. as given. With a load factor of 25 per cent, the maximum load would be 24,600 kw. but with an average of 6150 kw. the load factor would probably be as good as 35 per cent which gives a maximum of 17,600 kw. per substation.

With an average load of 6150 kw. the heating load per substation would be not less than 8200 kw., which would require 8000 kw. for regular service and 2000 kw. for spare, making a total installed capacity of 10,000 kw. per substation, which at $30.00 per kw. would amount to $300,000 per substation instead of $160,000, as given, or as a total for the four substations of $1,200,000 instead of $640,000 as given.

With the above changes, the cost of overhead construction bonding and substations would be:

96 miles overhead and bonds at $12,000	$1,152,000.
Sidings, same as given by Mr. Hobart	84,000.
Substations	1,200,000.
Total	$2,436,000.

On the basis of 16 per cent of first cost as given by Mr. Hobart, the fixed charges, maintenance and operation of substation (not including electric energy), would amount to **$389,760** instead of **$246,000** as given.

Note 17 states that, " It is desired to err on the side of favoring the steam locomotive whenever there is room for divergence of opinion." In view of this statement, it is not quite clear why he has used the 250 ton Mallett locomotive in handling the 600-ton train, or three of these locomotives for an 1800-ton train, where there is in actual service today a 300 ton Mallett locomotive which will haul a 900-ton trailing train on an average grade of $1\frac{1}{2}$ per cent at average speeds in excess of the 12 miles per hour assumed in this paper. Naturally, if fewer locomotives of a larger rating are used, the operating costs, such as fuel consumption, locomotive repairs, enginemen's wages, etc., will be materially reduced.

Also, the cost of 250-ton Mallets is given as **$45,000**. The 300-ton Mallet mentioned above costs new approximately **$33,500**, and the heaviest Mallet locomotives ever built (weighing 425 tons) cost slightly less than $44,000. It is evident that the figure of **$45,000** is much too high.

The foregoing analysis of Mr. Hobart's paper, (also of Mr. Kahler's paper), is based on West Coast operating conditions, as developed in the study of some of the most important heavy trunk lines operating over the Sierras. It shows that while he has made a favorable showing for the very general case he has assumed, his results, if applied to any of the concrete cases known to the office with which we are connected, would be disappointing to those who might be induced thereby to invest money, and who expect profit. Based on our experience, his estimated costs for overhead construction and substation equipment are very much too low; hence his electric operating costs are correspondingly low; he has considered steam locomotives only two-thirds as powerful as those now in service on our lines, and in his estimate of first cost, he has taken these comparatively small steam locomotives at a unit cost essentially the same as was paid for the largest steam locomotive ever built for West Coast work. His estimated first costs for steam locomotives are at least 30 per cent higher than West Coast practise shows to be reasonable, and his estimated steam operating costs are correspondingly high. In general then, according to our experience, the costs of steam operation have been magnified and the costs of electric operation minimized, in this, as in many other such very general solutions of a very complex problem.

F. W. Carter (by letter): The subject matter of the present papers is of great importance and discussion cannot fail to furnish valuable information. I think such papers as these are best written with a view of instructing or convincing the railway engineer rather than the electrical engineer, and the greatest care should accordingly be taken to avoid an undue bias in favor

of electrical working. But from the nature of the case, in which comparison is made between an established system and a newer rival, the figures for the established system are likely to be based on actual operation, and to cover a number of more or less trivial or accidental circumstances which are apt to be overlooked in making the comparison; I think there are signs of this tendency in both the present papers. For instance, in Mr. Hobart's express passenger proposition he adopts the figure of nine lb. per ton average train resistance; this is a reasonable figure considering that the mean train resistance is necessarily greater than the train resistance at the mean speed, and moreover that the figure includes the effects of curves, adverse weather, and other difficulties of the route. He, however, deduces his coal consumption directly from the work done against train resistance, suggesting an equipment efficiency of the order of 87 per cent. But the energy dissipated in final braking is of the order of 75 h.p-hr., and although townships are more sparsely scattered in the United States than in England it is doubtful whether a typical 100-mile run should have been assumed without some speed restrictions, each consuming, say, 60 or 70 h.p-hr., while a signal stop is not likely to be an infrequent occurrence. Altogether I think that to accord with actual operation, the coal consumption in the electrical case would have been better assumed 15 or 20 per cent greater than Mr. Hobart finds it to be. In the steam case I surmise that the corresponding figure is derived ultimately from the integral consumption in actual service, and therefore includes the effects of all the normal circumstances of such runs.

Mr. Kahler again seems to me, however, to have made his calculations without due regard to limitations that the traffic department may impose. He shows that it is possible to handle a certain tonnage of freight with but few more than half the number of locomotives in service than would be required under steam operation. This is certainly an engineering possibility, but if it is a commercial possibility, it is a pretty sure sign that the line is congested, and the proposition takes on an entirely new aspect on this account. Mr. Kahler assumes the average weight of train as 80 per cent of the maximum. Under English conditions, I believe this figure is nearer 60 per cent, but however this may be, the effect of increasing the capacity of the locomotive would in general be to reduce the figure by, say, 10 or 15 per cent. Many light trains would go forward at the instance of the traffic department without reference to the ultimate capacity of the locomotive. The number of freight locomotives required in actual service at any time would, I think, be nearly as great with electric operation as with steam.

Comparing Tables IX and XIII, I am inclined to think also that the number of electric passenger locomotives required is somewhat underestimated for the exigencies of traffic would

keep locomotives waiting in service, much as it does under steam operation. It would seem that in the case of the Butte, Anaconda and Pacific electrification, 23 steam locomotives are replaced by 17 electric, no such reduction as Mr. Kahler finds possible.

I note that Mr. Kahler has assumed the single-phase system of operation, but he seems to have based his estimate of locomotive repair cost on results obtained with continuous-current locomotives. Since the repair of the single-phase electrical equipment has been found to cost something like three times as much as for the corresponding continuous-current equipment. I am disposed to think his figures here a little too low, and I also think the number of his laid-up locomotives is on the low side for the same reason. His energy consumptions too appear to me somewhat low for normal operation, which Fig. 3 shows to have been contemplated, the frequent stops and intervals of running with brakes applied resulting in the dissipation of much energy. Although my contribution to the discussion is generally of the nature of criticism, I should like to express my appreciation of these very able and suggestive papers.

F. C. Merriell (by letter): The financial showing which has been so conservatively developed in these discussions finds very little consideration from railway operating officials, because of two fancied weaknesses which are believed to attend electric traction.

Frequent failure of electric locomotives in heavy traction service is believed by steam railway men to be inherent in a device, which to them, appears to be more complicated and less substantial than the steam locomotive, and even the most elaborate and painstaking analysis of the economies of electrification will not avail against this belief unless the operating experience of present electrifications shall prove that analysis to have been very conservative. The fact that partial failure of a steam locomotive is but little better than total failure while partial failure in an electric locomotive will usually not prevent it from getting in the clear, and perhaps making some progress until help can reach it, will have to be strongly urged even after the railway man has been convinced that of the two devices the electric is the simpler and the more substantial.

As appears in these discussions, the first divisions to be electrified will be those where heavy mountain work occurs and pusher service is required, and as these places are nearly always at high altitudes and subject to severe weather, steam railway men now believe that electric traction will, in such locations, meet obstacles which it cannot withstand. They admit the inefficiency of the steam locomotive to cope with extreme cold weather by their customary reductions in train tonnage as temperatures fall, which follows quite as much from the fact that the engines cannot make steam as from the poor conditions for traction. The electric traction man, on the other hand, expects his

motors to operate at greater loads during cold weather and is thus enabled to push his train tonnage up to the limit imposed by the condition of the track. Experience of heavy traction lines and such electrifications as are now in operation shows that distribution systems can be maintained without undue expense against the coldest and worst weather and will thus, contrary to the prevailing notion, cause less interference with traffic than engines which will not steam. The analysis of traffic movement on western roads will usually show that a part at least of the greatest congestions tends to lap over into extreme cold weather, as for instance the business of roads handling both deciduous and citrus fruits, which business will require much tonnage in deciduous fruit to be moved at the beginning of winter while tonnage in citrus fruits will become quite large before it ends, all of which should tend to make the advantage of electric traction appeal more strongly, as soon as the electrical fraternity is able to assure the railway operator that he can rely upon electrical machines for continuous service and few failures.

The stimulation to local main line traffic which is mentioned as possible with electrification can also profitably be extended to feeder lines and many of these which now operate at a loss might be brought nearer to a paying basis than they now are. It is the contention of railway officials that feeders as separate entities rarely make a profit (being principally valuable for the traffic they bring to the parent system), but the same standards of service, convenience, and efficiency, which the flexibility and economy of electric traction effect upon main line traffic, will without doubt render feeder lines more justifiable than they are considered at present.

H. F. Parshall (by letter): With reference to the two papers by Mr. Hobart and Mr. Kahler, I may say, speaking generally, that both papers would have been more convincing to railway engineers if accompanied by figures showing representative results obtained in good steam practise. According to my own experience and observations, both have assumed better results than are being obtained or are likely to be obtained in steam locomotive practice. The paper by Mr. Insull gave results obtained on several roads which led to the conclusion that the cost by steam locomotion is much higher than is commonly assumed. Personally, I think the time has past when the electrical engineer need adopt the position of apologist to the steam engineer.

The electric locomotive is *ab initio* the cheaper machine to operate. The real problem is to determine at what point the density of traffic is sufficient to justify the electrical installation. The fixed element is the conducting system between the locomotive and the power system. The cost of fuel of the electrical system under ordinary conditions is not more than half that with the steam system, but, on the other hand, the cost of the steam locomotive installation is not often more than 20 to 25 per cent

of the cost of the electric locomotive installation including the conducting system.

Under favorable conditions the cost of maintenance of the two systems is not very different. Under some conditions, however, the cost of maintaining the steam locomotive system must be materially greater. With cheap hydroelectric power and expensive coal, the electric system pays for itself with moderate traffic density. With increasing labor difficulties and increasing cost of fuel, the case of the electrical system becomes every day stronger, as less men, less skilled mechanics and less fuel are required with the electrical system.

From a strictly operative point of view, my own experience is limited to my activities as Chairman of the Central London Railway. I had designed the system, including the power station and had advised in its operation for some years, but after becoming Chairman, I had to see through two strikes, one a general railway strike and the other a general colliery strike. During the general railway strike, the power station, as the heart of the railway, was a special cause of anxiety. In the coal strike, every department of the railway was crippled. To keep the power station supply assured, special efforts, in addition to the usual ones, had to be made. While I have been largely associated with electric power installations, I came to the conclusion that railway managers had enough to do without embarking on that class of business. Further, that the central power undertaking is in a better position to guarantee a supply under all conditions than any railway company can hope to be, and also, owing to the diversity conditions, can supply cheaper. With the question of supply settled, the electrical system of traction is in a stronger operative position than the steam system.

As to the type of locomotive for heavy freight work, with moderate facilities for repair, I should prefer the side-bar type with motors individually replaceable. The maintenance of such a locomotive is small and the time to carry out repairs a minimum. Axle driven types of either locomotives or motor cars require a higher degree of skill in maintenance and operation.

With reference to the voltage of the overhead conductor system, owing to the small cost of the conductors as compared with the supporting structure there appears small advantage in exceeding 2500 volts. The size of overhead conductor is largely determined by the maximum current required by the individual trains, so that with increasing traffic density the growth is met by increasing the number of substations without reducing the efficiency. In the case of a line 400 miles in length I made a careful study as between 5000 and 2500 volts d-c. overhead conductor pressure, and came to the conclusion that the saving by the higher voltage was too small to affect the general result. In the case of the 2500-volt installation, the motors could be safely worked at full line voltage which in my judgment is a material advantage in heavy railway working.

I am glad to see evidence in these two papers that a truly commercial spirit is coming into effect in considering railway problems.

Charles P. Kahler: The foregoing discussion was very interesting to me, in that, although some speakers confined their remarks to the narrow limits of system of electrification, types of locomotives, and other details, the comparative economics of steam and electric railroad operation, which is really the most important part of the problem, received considerable attention. The data and other information given in my paper, "Trunk Line Electrification," was a comparison between steam and electric railroad operation, and the paper could hardly be classed as advocating any system of electrification, although Mr. Armstrong seems to think it does.

Mr. Armstrong states that the electrification costs depend principally upon the locomotives, substations, and trolley and feeder copper, and that the locomotive costs are high in the case of the single-phase system, while the substation and trolley and feeder wire costs are high in the case of the direct-current system. This is approximately true, considering the single-phase commutator motor locomotive alone, but the locomotive cost would not necessarily be so materially different from the direct-current system if the split-phase locomotive, or the mercury vapor rectifier locomotive to which he refers, were used.

Mr. Armstrong assumes that the substation and trolley and feeder copper costs remain constant as the traffic increases, while the locomotive costs increase as the traffic increases, and draws the conclusion that, even though the single-phase system proves most economical with moderate traffic, as far as first cost is concerned the direct-current system will, when considered with a 50 per cent or 100 per cent traffic increase, be most economical. Mr. Wynne mentioned two electrically operated railroads where the substation and copper line costs have been materially increased by an increase in traffic, which shows the incorrectness of Mr. Armstrong's premises, and as a consequence, makes his conclusions wrong.

Very few railroad improvements involving any large sums are made without a thorough investigation by the railroad officials of the effect of increasing the traffic. Practically none of the important line or grade changes with which I have been connected were made without considering the effect of at least doubling the traffic. In our investigations of steam railroad electrification, we have gone still further and besides considering the effect of a change in the volume of traffic have also considered the effect of electrification upon the whole railroad, rather than confining our studies to isolated sections. As a result of numerous studies of this character, I am inclined to believe that electrical engineers, who are usually unacquainted with actual steam railroad operating conditions, would be very much slower in advocating thier own particular fancies if their effect on the whole system was first considered.

The substation and feeder copper cost for a direct-current system which would be of sufficient capacity to permit the operating of trains under such close headway as would be possible on a steam-operated railroad during a congestion or other emergency, would usually be so great as to make electrification unwarranted for many years. As is generally known, the electric distribution system of a direct-current line is not generally designed for any possible emergency, but an allowance is only made for a reasonable contingency, which often is determined by electrical men not familiar with steam railroad operation. On the other hand, it would be commercially possible with a high-voltage trolley, such as is used on single-phase systems, to provide a distribution system which could expeditiously handle almost any congestion or emergency which a steam-operated railroad could.

The development of the mercury arc rectifier locomotive, of which Mr. Armstrong speaks, will no doubt be welcomed by all interested in heavy electric traction work, since direct-current locomotives—which are preferred by Mr. Armstrong and other advocates—can, through the mercury arc rectifier, be made to operate by current from a single-phase trolley. If this new locomotive serves no other purpose than the settlement of the system question, it will have done good service.

The introduction of the mercury vapor rectifier locomotive, together with the split-phase locomotive, which can also be operated from a single-phase trolley, would indicate that the single-phase system, besides providing low cost substations and low cost distribution system, has a further advantage in being adaptable to four or five different types of locomotives.

Mr. Babcock's remarks about inaccurate conclusions being liable to result from generalizing are hardly in accord with his criticism of load factor. He compares his estimated load factor for the proposed electrification of the Southern Pacific lines over the mountain ranges surrounding the Central California valley—which are short in length and where the average grades are heavy—with a long line of railroad with light average grades. It would require about a day and a half for freight trains to cover the 468 miles of line and the stopping or starting of a train at either end of the line would not make a large increase or decrease in the total load, as there would be so many more trains in simultaneous operation on the line, which would not be the case with the shorter line where only a few hours were required to make the run. In fact, the daily load factor would be very high for the longer line.

The California lines have to contend with the heavy freight traffic during the fruit season, whereas on the 468-mile line discussed in my paper the peak of the west-bound business, of which coal forms a considerable portion, does not happen at the same season as the peak of the east-bound traffic, of which lumber forms a large proportion. Also, the maximum passenger traffic

does not occur at the same time as either the peak of the eastward or westward freight traffic. The above, I believe, shows why it is possible to get an annual load factor of 60 per cent for the 468-mile line and only 20 per cent for the short mountain lines to which Mr. Babcock refers.

I cannot check Mr. Babcock's statement that the purchase of electric power at a greater rate than 5 mills per kw-hr. would be utterly prohibited where oil is selling at from 70 cents to 80 cents per barrel. Three barrels of oil are equivalent to one ton of coal, allowing for the higher efficiency of the oil-burning power plant, which would be equivalent to coal at from $2.10 to $2.40 per ton. With a load factor of 20 per cent, the fuel cost alone would not be far below 5 mills per kw-hr., and when the fixed charges and the other operating expenses were added a rate of 5 mills would appear to me low, especially as nothing was allowed for freight on oil or additional charges for transmission lines in case the power plant is built near the oil fields.

Hydroelectric power is at present being sold at as low a rate as the above in many sections of the West. I quoted in my paper the rate of 5.36 mills per kw-hr. which the Great Falls Power Company has given the Chicago, Milwaukee & St. Paul R.R. Also in some sections of Southern Idaho power for heating and irrigation pumping is obtained at even lower cost.

Mr. Carter doubts the practicability of making a reduction in the number of freight trains, for traffic reasons, even though the electric locomotives can haul heavier freight trains. Without going into any technical discussion, I would advise that a number of Mikado locomotives, whose tractive power is about 15 per cent greater than the consolidated locomotives, has lately been put in operation on one of the engine districts of the 468-mile line, and an actual reduction in the number of freight trains has resulted. Further, on another division, where conditions were somewhat similar, the train weights were increased by reducing the grades, resulting in a material reduction in the number of freight trains.

For English conditions, Mr. Carter gives the average freight train weights at 60 per cent of the maximum. The figure of 80 per cent given for the 468-mile line considered in my paper was not assumed but was an actual record. This has been increased to 86 per cent for the fiscal year ending June 30, 1913, being 91 per cent for west-bound trains and 82 per cent for east-bound trains.

The possibility of handling the given freight tonnage with only 43 electric freight locomotives has also been questioned, although Mr. Carter qualifies his remarks with the statement that if this can be done it is a pretty sure sign that the line is congested. While this is true, the congestion is partly caused by the equipment troubles on the two helper districts near terminal No. 2.

The train sheet in Fig. 3 was for the day of maximum traffic. Of the freight trains shown, only two are scheduled; the re-

mainder being run as extra. This maximum day train sheet shows that only six freight trains were in simultaneous operation on engine district No. 1, six on district No. 2 and seven on District No. 3, a total of 19 freight trains, requiring 19 freight road locomotives. Additional locomotives would, of course, have to be allowed to provide for helper locomotives, time in enginehouse, shops, etc., but it should be remembered that at the time of maximum demand there would generally be a minimum number of locomotives in the enginehouse. As stated in the paper, the number of electric freight locmotives required is based upon the number of steam locomotives actually used to handle the traffic, allowing for the reduction in the number of freight trains by electric operation and the fact that an electric locomotive is nearly always ready for service and needs to spend little time in the enginehouse I judge my estimate of 43 electric freight locomotives not only to be large enough to handle the given tonnage but also to provide a larger margin than is usually allowed for steam service.

With regard to the number of electric passenger locomotives, it should be mentioned that of the the three through passenger trains each way per day shown, one is really a solid mail train. No extra mail trains are operated and the number of passenger trains operated in addition to the two through passenger trains scheduled is small, which will account for the apparent narrow margin allowed in the number of electric passenger locomotives. Further, it was proposed to make districts Nos. 1 and 2 one passenger run, there being no objection to this on account of grades or a 16-hour labor law, as would be the case with freight trains. This practise of making the passenger runs double the freight runs is now being followed on some districts with steam locomotives.

In the case of local passenger traffic, the volume is not so uniform as the through traffic, on account of state and county fairs and other things requiring excursion and extra trains, but 14 motor cars were allowed for this purpose. Most of these local extra trains are operated on the west end of the line and the extra cars allowed can be held in readiness at terminal No. 2.

Possibly Table VI, in regard to number of trains, as compiled, should have some explanation to make things clear. The figures shown under the maximum day column mean the total number of trains on the maximum day. The maximum day of passenger traffic does not happen at the same season of the year as maximum freight traffic, as stated, and although the 16 freight trains shown under the maximum day column of district No. 1 are the maximum number, the 10 passenger trains shown in the same column are not the maximum number of passenger trains operated but only the number operated on the maximum day for both passenger and freight traffic. The total number of trains per day, 26 as shown for district No. 1, is, of course, the maximum number for the year. The same applies to the other districts.

The number of passenger trains in the average day column is given in round numbers to simplify computations, the actual figures being 10.5 passenger trains for district No. 1; 8.2 trains for district No. 2 and 8.1 trains for district No. 3, the extra trains being principally local trains. Since the number of passenger trains was taken the same for both steam and electric operation, this would not materially affect the results, which would not be the case for freight service, and the exact freight train figures had to be used.

Although some direct-current locomotive repair costs were quoted in my paper, the electric locomotive repair costs used in the estimates were based upon a study of the comparative repair expenses of the different parts of steam and single-phase electric locomotives, as outlined on page 1087, which shows that it was estimated that a single-phase locomotive would cost about 45 per cent as much as a steam locomotive for repairs. For the direct-current locomotive costs quoted, this per cent gets as low as 36.5 per cent; showing that an allowance was made for the relative cost of alternating-current and direct-current locomotives.

The foregoing answers most of the questions put by Messrs. Hall and Welsh. The estimated cost of the steel tower transmission line was based upon the actual cost of a steel tower line lately built parallel to the railroad, the material being distributed by work trains on the railroad, and, if anything, is high.

Catenary construction was, of course, proposed for the high-voltage trolley line. The figures quoted by Messrs. Hall and Welsh appear high even for California conditions, or else they include the cost of the copper trolley.

A number of Mr. Murray's remarks are worthy of careful consideration, especially as he does not underestimate the steam locomotive. He believes that in making comparisons between steam and electric operation of railroads some consideration should be given to the improvement of the steam service, and there is no question but that more consideration will be given to steam railroad electrification by both operating and financial railroad men if the matter is presented in this way. For instance, steam operation of the 468-mile line discussed in my paper could be improved by the use of Mikado locomotives for freight service instead of consolidated locomotives, and by revising both the ruling and helper grades. However, this would take very nearly as much money as required for electrification and the reduction in operating expenses would not, with the present traffic, pay the fixed charges on the investment, while by electric operation a fair return would be had on the investment.

The numerous advantages of substituting electric power for steam on mountain grades, mentioned by Mr. Hill and Mr. Merriell, are generally conceded even by many steam railroad men, and are in accord with investigations made of mountain grades on our lines. Mr. Babcock seems the only one unable to make any showing for electrification on mountain grades.

Our investigations would also indicate that many engine districts of only moderate grades could be more economically operated by electric power than by steam, and in some instances show up better than even the mountain sections; the reason being that on some moderate grade sections the number of freight trains can be very much reduced by electric operation on account of the characteristic of the electric locomotive to operate at overload for short periods. On mountain grade sections, however, the continuous rating of the motors is more important, and although some reduction can generally be made in the train service it is not as great as can often be made on some moderate grade engine district where the ruling grades are short.

(To be continued.)

THE I. E. C. MEETING AT BERLIN

Advance Report to the U. S. National Committee on the Berlin Meeting of the International Electrotechnical Commission

The following report is intended to outline the results attained at the recent meeting of the I. E. C., in Berlin, (September 1st to 6th, 1913) for the information of the U. S. committee-members, in advance of official reports from the General Secretary of the Commission, with respect to which official reports, this preliminary statement must of course be subordinate, and subject to amendment in detail.

The Berlin meeting was the fifth meeting which the I. E. C. has held; but it was the second plenary meeting, since three of the meetings have been of semi-official character only. It was well attended, since 24 nations were represented by some 70 delegates, all told. It was the first meeting held in Germany, and the German Government was represented by President Dr. E. Warburg of the Physikalisch-Techniche Reichsanstalt, Geheimrat Dr. K. Stecker, Dr. Jaeger, and others.

In the absence of the President of the I. E. C., Dr. Budde, who was unfortunately prevented by illness from attending, Dr. Warburg presided at the official opening on September 1st. An address of welcome was read by Dr. Lewald, the Director of the German Ministry of the Interior. The address was responded to by Prof. Paul Janet of the Laboratoire Centrale de Paris. Mr. Alexander Siemens presided at the official closing meeting.

The sessions of the Commission at Berlin were of four kinds; namely (1) official plenary meetings of formal opening and final ratification, (2) international sub-committee meetings on special subjects on the 1st and 2nd Sept., where the hardest work, was, naturally, undertaken; (3) unofficial or working meet-

ings, on 3rd and 4th Sept., at which the sub-committee reports were presented to the main body, discussed, and acted upon; and (4) a final Council meeting for the election of officers for the ensuing term, and other formal administrative business.

There were four international sub-committees appointed at Turin in 1911, two of which had been in existence prior to the Turin meeting; these committees were constituted and convened as follows:

Subject	Members, one from	Dates of Meeting	Places of Meeting	Chairman at Berlin
Nomenclature	France Germany Great Britain	March, 1912 March, 1913 September, 1913	Paris Cologne Berlin	Prof. S. P. Thompson
Symbols	Belgium France Germany Great Britain Italy Sweden Switzerland United States	March, 1912 January, 1913 September, 1913	Paris Zürich Berlin	Geh. Dr. K. Strecker
Rating of Electrical Machinery	Belgium France Germany Great Britain Italy Sweden Switzerland United States	May, 1912 January, 1913 September, 1913	Paris Zürich Berlin	Herr Huber-Stockar
Prime movers in connection with Electrical Plant	Austria France Germany Great Britain Italy Norway Spain Sweden Switzerland United States	January, 1913 September, 1913	Zürich Berlin	Dr. H. Zoelly

Nomenclature. The committee on Nomenclature presented an excellent report, which was adopted at the plenary meeting. It contained some 80 electrotechnical terms and definitions, in English and French. The list is too long to be presented in this outline report.

Symbols. The committee on Symbols submitted a report,

in French, which was adopted at the plenary meeting. An English rendering is appended hereto as Appendix A. It will be seen that symbols have been internationally agreed upon for 36 quantities. In cases of nearly half of them, however, (16), agreement could not be reached upon a single symbol; so that for these an alternative is offered. Designating letters, or letter-groups, are provided for 15 electrical units in common use. Standard abbreviations for 29 metric units are also agreed upon. Seven common mathematical symbols are recorded, including both i and j for $\sqrt{-1}$, according to the preference of the writer.

Rating. The committee on Rating was confronted with an exceptionally heavy task. This committee held meetings in Paris in 1912 and in Zurich in 1913. It published its work at those meetings under I. E. C. Publications Nos. 17 and 20. Moreover, General Secretary leMaistre, in I. E. C. Publication 9, of August, 1911, presented the electric machinery rating rules of various countries in a form adapted to comprehensive comparison. Yet in spite of all this preliminary work, it was found that essential issues leading to an international rating for such machinery had not been clearly formulated when the Rating committee met in Berlin. In fact, considering our own committee alone, it is debatable whether a satisfactory technical basis for the rating of electrical machinery had been reached in America prior to the Midwinter Convention of the A. I. E. E., held under the auspices of its Standards Committee, in February, 1913. Consequently, the fact that complete international agreement upon international rating rules was not reached at Berlin need not occasion great surprise.

Just before the Berlin convention of the I. E. C., the U. S. delegation had the advantage of meeting with a Section of the Engineering Standards Committee of Great Britain, which included the British delegation—in London on Aug. 23rd, and again in Berlin, on Aug. 31st. At these meetings the viewpoints of the British and American committees were carefully compared, and adjusted into uniformity on many matters relating to international rating. In effecting this valuable parallelisation of technical views between the two committees, Mr. H. M. Hobart of our committee rendered signal service. The complete conformity between the views of these two national committees on the points of immediate importance in Rating was probably helpful to the I. E. C. International Committee on Rating, in reaching a clear determination of the extent to which

international opinion was in agreement or disagreement, thus paving the way for reaching a final agreement at some future convention, let us hope at San Francisco.

Complete agreement was reached in the I. E. C. Rating Committee on the principle of defining the rating of an electrical machine, so far as thermal behavior is concerned, by a limiting internal or "hottest spot" temperature, as judged by a definitely lower maximum measured temperature attained in the apparatus. A list of such maximum permissible measured temperatures for certain different classes of insulation was agreed on for machines up to four kv. in e.m.f. In order, therefore, to fix upon the international rating, it was only necessary to settle upon an internationally conventional reference-temperature, or circumambient room-temperature. Thus, in the case of impregnated cotton windings, up to four kv., the maximum permissible measured temperature was set at 90 deg. cent. If the international reference temperature, or initial ambient temperature, is taken as say 40 deg. cent., then it follows that the international rating of a machine for continuous service is that output which will finally bring the measured accessible temperature from 40 deg. to 90 deg. cent., or will establish a temperature rise of 50 deg. cent. When working at an actual ambient temperature of 40 deg. cent., the available output would be the same as the international rating. When working at an actual ambient temperature of say 30 deg. cent., the available output would be greater than the international rating, roughly in the ratio $(60 / 50)^{\frac{2}{3}}$ or say 1.13; whereas, when working at an actual ambient temperature of say 50 deg. cent., assuming that the shunt windings of the machine could be operated at so high a temperature, the available output would be less than the international rating, roughly in the ratio $(40/50)^{\frac{2}{3}}$, or the machine would have to be derated about 16 per cent. The advantage of selecting a fairly high international ambient temperature is that the number of localities will be reduced in which, by reason of climatic or locally developed high temperatures, the machine must be derated, or the purchaser warned against taking from it an output equal to its international rating. On the other hand, a fairly low international ambient temperature has the advantage of increasing the international rating of a given machine. That is, a fairly high international ambient temperature makes for safety in applying a load equal to the rating, under summer conditions of service, but tends to diminish the rating.

It is only reasonable to expect that cool countries, lying on the anti-torrid sides of the temperate zones, should desire to set their local or national ambient temperatures correspondingly low, so as to avail themselves of the full benefit of greater available output that their cool climates permit, and that such countries should prefer to have the international ambient temperature set at the same level, so as to have the same rating internationally as locally; even if the machines have frequently to be derated in warmer climates or in engine rooms. So too, it is likewise reasonable to expect that countries subject to warm weather in summer should prefer to have a higher and safer ambient temperature in their local or national standardization rules, in order to avoid frequent derating.

It was found that the great majority of the delegates at the Berlin meeting favored 40 deg. cent. for the ambient temperature of reference, as recommended at the A.I.E.E. midwinter convention, with an international continuous rating for machines of impregnated cotton winding corresponding to 50 deg. cent. rise. But two countries of northern Europe held out for 35 deg. cent. ambient temperature, and therefore a rating based on 55 deg. cent. rise. The delegates from those countries intimated that the 50 deg. cent. rise rating, as recommended for the A. I. E. E. Standardization Rules, was over-conservative, and that a rating based on 55 deg. cent. rise, or nearly 10 per cent more, was safe and proper. The 50-deg. cent.-rise delegates maintained, on the other hand, that the majority of places in the habitable world, where dynamo-electric machinery was operated, were subject to distinctly higher summer ambient temperatures than 35 deg. cent.; so that it was to the interest of international electrical engineering that the international rating should be kept down to a conservative value, in order to minimise the need for summer derating, or precautions against summer overheating under international rating load. No agreement could therefore be reached, and the question of ambient reference temperatures was referred back to the various national committees for further consideration.

On all other points of immediate importance to continuous rating, agreement was reached. Thus, it was admitted that overloads should not be recognized in international rating; *i.e.*, that an international rating for continuous service should specify one maximum permissible output only, and recognize no extras; although it would manifestly lie within the province

of an operating engineer to increase the load above the international rating load in winter time, or under any conditions when the temperatures attained in the machine were well below the specified maximum permissible limits. As soon, therefore, as an international ambient temperature can be agreed upon, international rating of the great majority of machines will thereby be immediately determined. At the present time, however, it is manifest that one and the same machine is subject to different ratings in different countries; or, in other words, that different countries rate their machines in a materially different way.

The report of the I.E.C. Rating Committee, shorn of all specifications as to international ambient temperature, or as to temperature rise for the international rating, was then adopted by the plenary meeting, and will doubtless be issued by the Central office in due course. The list of maximum permissible measured temperatures appears in Appendix B herewith.

Prime Movers. The committee on Prime Movers presented an excellent report dealing mainly with the definitions and nomenclature of hydroelectric installations. This report was also adopted by the plenary meeting, and may be expected to appear later in the official proceedings of the Berlin Meeting.

Annealed Copper Standard. The subject of an International Standard of Annealed Copper was also dealt with at the convention. It will be remembered that the Bureau of Standards, at the request of the A. I. E. E. Standards Committee, took up, in 1910, the computation of a new Standard Copper Wire Table; because recent investigations had shown that the temperature coefficient of resistivity employed in the old Institute Copper Wire Table, computed by the Standards Committee in 1893 from Matthiessen's data, was inaccurate. The Bureau undertook the task,* and made an extensive preliminary investigation of both the resistivity and the resistivity temperature-coefficient of copper wire employed industrially in America. The Bureau found that the mean value of resistivity of good annealed industrial copper in the United States, expressed in terms of the meter-gram, or resistance of a wire one meter long weighing one gram, was, at 20 deg. cent., nearly 0.153 ohm; whereas Matthiessen's standard, as interpreted in the A. I. E. E. TRANS-

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*See Circular No. 31 of the Bureau of Standards, "Copper Wire Tables", 2nd Edition, January 1, 1914.

ACTIONS, was represented by a meter-gram of 0.15302 ohm at 20 deg. cent. Consequently, the Bureau accepted the meter-gram of 0.15302 international ohm at 20 deg. cent. as the annealed copper standard, with a temperature-coefficient of 0.00393 per deg. cent. from and at 20 deg. cent. In 1911, the Bureau prepared to issue new wire tables based on the above values. When, however, these data were presented to electrical engineers in Europe, with a view to arriving at an international agreement on the electrical properties of standard annealed copper wire, small differences in data among the various countries revealed themselves. A proposal was then made, in Germany, to adopt a standard copper conductivity as represented by a conductance of 58.00 mhos in an annealed copper wire, at 20 deg. cent., having a length of one meter and a cross-section of one sq. mm. Such a standard corresponds to a meter-gram of 0.15328 ohm at 20 deg. cent. This proposal met with general favor among the National Physical Laboratories, was endorsed by the Bureau of Standards in 1912, approved by the Standards committees of the A. I. E. E. and the A. S. F. T. M. in 1912, recommended by the Rating committee of the I. E. C. in 1912, was finally agreed to, in the French text, by representatives of the National Physical Laboratories in Berlin last September, and was forthwith adopted by the plenary meeting of the I. E. C. A translation into English of the French text appears in Appendix C, herewith.

The adoption of one and the same electrical standard resistivity and temperature-coefficient by the National Laboratories of France, Germany, Great Britain and the United States, as well as by the I. E. C. at Berlin, should ensure complete agreement between the future standard copper-wire tables in all parts of the world, on a conductivity basis substantially the same as Matthiessen's standard. In fact, the differences which have existed during the last few years between the electrical copper standards of the different countries have been unimportant commercially; but have yet been sufficiently large to confuse their numerical comparison. By the action at Berlin, these small numerical discrepancies should in future disappear.

At the Council meeting which followed the plenary meeting, M. Maurice Leblanc, of Paris, was unanimously elected as the President of the I. E. C., to succeed Dr. Budde. It is expected, therefore, that he will preside at the next meeting, at San Francisco, in 1915. Col. Crompton was also unanimously reelected as Honorary Secretary.

An important decision was arrived at in the Council meeting, to the effect that the French text shall henceforward be considered as the text of reference, and that all other texts shall be considered as translations therefrom. French is more familiar to the delegates at large than any other single language, and the difficulty of maintaining two official records side by side in different languages is very great. They can never be brought into such exact equivalence that reference to each, in case of minutious enquiry, will give exactly the same result. Moreover, by having a single reference language, opportunity is opened for adding, in future, other admitted languages of the Commission to the printed records, at owners' risk and expense, thereby extending the literary usefulness of the Commission's publications.

The Spanish delegates invited the Special committees to hold the next meeting in Madrid, and this will probably take place next April. Prof. Chatelain, the Russian delegate, on behalf of his committee, officially invited the I. E. C. to hold a plenary meeting, in 1917, at St. Petersburg.

The German committee, in view of the large amount of work to be done at the meeting, very considerately refrained from overtaxing the delegates with social engagements. The entertainments they offered, were, however, excellent in character, and were greatly appreciated.

The U. S. delegates attending the meeting were President C. O. Mailloux, and Messrs. Bell, Hobart, Kennelly and Sharp. Mr. Mailloux was elected the President of the unofficial meetings, where the duties devolving on the presiding officer are numerous and exacting.

At the plenary meeting, President Mailloux, in pursuance of the invitation given in the first instance by President Dunn at Turin, extended a cordial invitation on the part of the A. I. E. E. and the American Committee, to hold a meeting of the I. E. C., and an International Electrical Congress, at San Francisco, in 1915. This invitation has already been accepted, and we may hope that a large and representative meeting will be held there the year after next.

Respectfully submitted,

A. E. KENNELLY
Secretary U. S. Committee.

APPENDIX A

An English rendering of the Report of the Special Committee on Symbols adopted in French at the Berlin plenary meeting of the I. E. C.

General Remarks

By confining oneself to Electrotechnics alone, it would seem possible to standardize symbols. The following rules may serve as a guide to the attainment of this object:

The symbols must be clearly distinguishable one from another when writing with a pen on paper, with chalk on a blackboard, and with a typewriter. In the printed text, it is advisable to use a different type for the symbols from that of the text. It is desirable that in ordinary handwriting, one should not be obliged to add distinctive signs to symbols to specify the type to be employed. It should be possible to spell out the symbols when writing them on the blackboard. Finally, preference should be given to those symbols already in common use. From this it will be seen that it is impossible to make a distinction, in ordinary handwriting, between Roman letters and Italics, and that small roundhand letters, being too difficult to differentiate from the above, cannot be used. It is generally agreed to abandon Gothic type, as requiring too long a time in writing. Finally, many of the Greek capitals are identical with Roman capitals. Taking the above points into account, there remain about one hundred symbols available in Roman, Script and Greek type, of which several are already used for mathematical symbols and which are necessary for the purposes of the electrician. A list of symbols most frequently needed in electrotechnics is appended herewith. Taking into account certain symbols which are occasionally made use of, it is obvious that there will be none left for purely physical or mechanical quantities. Thus one may have, in the same formula, electrotechnical symbols as well as others used in mechanics and physics generally; this is especially the case in equations containing mass, moment of inertia, speed, density, temperature, quantity of heat, etc. The Special Committee on Symbols suggests, therefore, that in such cases, for physical and mechanical quantities, the symbol habitually used by physicists and mechanical engineers should be employed, if this symbol does not already exist in the formula as an electrotechnical symbol. If, on the contrary, it already exists in the formula, it is desirable that it be accompanied by a distinctive sign or that the notation be changed.

Special Propositions

RULES FOR QUANTITIES

(*a*) Instantaneous values of electrical quantities which vary with the time to be represented by small letters. In case of ambiguity, they may be followed by the subscript "t".

(*b*) Virtual or constant values of electrical quantities to be represented by capital letters.

(*c*) Maximum values of periodic electrical and magnetic quantities to be represented by capital letters followed by the subscript "m."

(*d*) In cases where it is desirable to distinguish magnetic quantities (constant or variable) from electric quantities, magnetic quantities should be represented by capital letters of either script, heavy-faced, or other special type. Script letters should not be used except for magnetic quantities.

(*e*) Angles should be represented by small Greek letters.

(*f*) Dimensionless and specific quantities should be represented wherever possible by small Greek letters.

1. Ordinary numerals as exponentials shall exclusively be used to represent powers. (In consequence, it is desirable that the expression $\sin^{-1} x$, $\tan^{-1} x$, employed in certain countries, be expressed by arc sin x, arc tan x.)

2. The comma and the full-stop shall be employed according to the custom of the country, but the separation between any three digits constituting a whole number shall be indicated by a space and not by a full-stop or a comma (1 000 000).

3. For the multiplication of numbers and geometric quantities, indicated by two letters, it is recommended to use the sign $\times$, and the full-stop only when there is no possible ambiguity.

4. To indicate division in a formula, it is recommended that the horizontal bar and the colon be employed. Nevertheless the oblique line may be used when there is no possibility of ambiguity; when necessary, ordinary brackets (), square brackets [], and braces {} may be employed to obtain clearness.

Tables of Symbols Proposed—I. Quantities

Name of Quantity	Symbol	Symbol recommended for the case in which the principal symbol is unsuitable
1. Length	l	In dimensional equa-
2. Mass	m	tions the capital let-
3. Time	t	ters L, M, T, are to
4. Angles	α, β, γ ...	be employed.
5. Acceleration of gravity	g	
6. Work	A	W
7. Energy	W	U
8. Power*	P	*
9. Efficiency	η	
10. Number of turns in unit of time	n	
11. Temperature centigrade	t	θ ϑ
12. Temperature absolute	T	Θ
13. Period	T	
14. Angular frequency ($2\pi/T$)	ω	
15. Frequency	f	ν **
16. Phase displacement	φ	
17. Electromotive force	E	
18. Current	I	
19. Resistance	R	
20. Resistivity	ρ	
21. Conductance	G	†
22. Quantity of electricity	Q	
23. Electrostatic flux-density	D	
24. Capacity	C	
25. Dielectric constant	ϵ	
26. Self-inductance	L	$\mathcal{L}$ or heavy-faced or special type.
27. Mutual inductance	M	$\mathcal{M}$ or heavy-faced or special type.
28. Reactance	X	$\mathfrak{X}$
29. Impedance	Z	$\mathfrak{Z}$
30. Reluctance	S	$\mathcal{R}$ or heavy-faced or special type.
31. Magnetic flux	Φ	$\mathfrak{F}$ or heavy-faced or special type.
32. Magnetic flux-density	B	$\mathcal{B}$ or heavy-faced or special type.
33. Magnetic field	H	$\mathcal{H}$ or heavy-faced or special type.
34. Intensity of magnetization	J	$\mathfrak{J}$ or heavy-faced or special type.
35. Permeability	μ	
36. Susceptibility	κ	

* A symbol for "Power," in the second column, is left "with power" to the Austrian and German committees, to be inserted by them.

** This letter ν may be suppressed later at the instance of the Austrian and German committees.

† A symbol for conductance in the second column is left "with power" to the Austrian and German committees, to be inserted by them.

¶ The German delegate makes reservations as to symbols Nos. 13, 14, 20, 23, 25, 27 to 31, which are not yet accepted in Germany, but does not oppose their adoption by the I. E. C.

II. UNITS. SIGNS FOR NAMES OF UNITS

Sign for names of Electrical Units to be used only after numerical values.

Name of Unit	Sign
1. Ampere	**A**
2. Volt	**V**
3. Ohm	*
4. Coulomb	**C**
5. Joule	**J**
6. Watt	**W**
7. Farad	**F**
8. Henry	**H**
9. Volt-coulomb	**VC**
10. Watt-hour	**Wh**
11. Volt-ampere	**VA**
12. Ampere-hour	**Ah**
13. Milliampere	**mA**
14. Kilowatt	**kW**
15. Kilovolt-ampere	**kVA**
16. Kilowatt-hour	**kWh**

m	sign for milli-
k	sign for kilo-
μ	sign for micro- or micr-
M**	sign for mega- or meg-

* One or other of the symbols **O** and **Ω** is recommended provisionally to represent the ohm. The symbol **Ω** should no longer be employed for the megohm.

** Greek capital letter.

III. MATHEMATICAL SYMBOLS AND RULES

Name	Symbol	Symbol recommended for the case in which the principal symbol is unsuitable
Total differential	**d**	*d*
Partial differential	δ	
Base of Napierian logarithms	**e**	ϵ
Imaginary $\sqrt{-1}$	**i**	**j**
Ratio of circumference to diameter	π	
Summation	Σ	
Summation, integral	$\int$	

IV. MISCELLANEOUS ABBREVIATIONS FOR WEIGHTS AND MEASURES.

Length: m; km; dm; cm; mm; μ = 0.001 mm.
Surface: a; ha; m^2; km^2; dm^2; cm^2; mm^2.
Volume: l; hl; dl; cl; ml; m^3; km^3; dm^3; cm^3; mm^3.
Mass: g; t; kg; dg; cg; mg.

Speed Notation

The Special Committee on Symbols refers the question of finding a suitable name for "speed of rotation expressed in revolutions per minute" to the Special Committee on Nomenclature.

The I. E. C. recommends to the International Electrical Congress of San Francisco the adoption of the name "Siemens" for the practical unit of conductance.

APPENDIX B

Limits of Observable Temperatures Adopted by the I. E. C. in September, 1913

Applicable only to windings for rotating machinery, the terminal pressures of which do not exceed 4000 volts, and to dry transformers with solidly impregnated coils up to 10,000 volts.

Non-impregnated cotton	80	deg.	cent.
Impregnated cotton or paper—general	90	"	"
" " single-layer field coils, stationary or moving)	95	"	"
" " stationary coils solidly impregnated throughout	95	"	"
" " Rotor and stator windings having the slot portion solidly impregnated or moulded	95	"	"
Enamelled wire (without cotton)	105	"	"
Mica, micanite, asbestos—general	115	"	"
" " single-layer field-coils, stationary or moving	120	"	"
" " stationary coils solidly impregnated or moulded	120	"	"
Windings permanently short-circuited.			
Insulated	100	"	"
Non-insulated	110	"	"
Commutators—slip rings	90	"	"
Bearings	80	"	"

The temperature limits for oil-immersed transformers were not assigned.

APPENDIX C

Translation from the French text adopted at Berlin on the *Annealed Copper Standard.*

REPORT OF THE NATIONAL LABORATORIES CONCERNING AN INTERNATIONAL STANDARD FOR COPPER

I. ANNEALED COPPER

The following values should be taken as normal for annealed standard copper.

1. At 20 deg. cent., the resistance of an annealed copper wire 1 meter long and having a uniform cross-section of 1 sq. mm. is 1/58 ohm = 0.017241...ohm.

2. At 20 deg. cent., the density of annealed copper is 8.89 grams per cu. cm.

3. At 20 deg. cent., the coefficient of variation of resistance with temperature of annealed copper, measured between potential terminals rigidly attached to the wire (constant mass), is 0.00393 = 1/254.5 per deg. cent.

4. Consequently, it follows from (1) and (2) that, at 20 deg. cent., the resistance of an annealed copper wire of uniform cross-section 1 meter long and having a mass of 1 gram is $(1/58) \times 8.89$, or 0.15328...ohm.

II. INDUSTRIAL COPPER

1. The conductivity of annealed copper should be expressed at the temperature of 20 deg. cent. in percentage of that of standard annealed copper, and ordinarily to a precision of 0.1 per cent.

2. The percentage conductivity of annealed industrial copper should be computed in accordance with the following rules:

(*a*) The observation temperature should not differ from 20 deg. cent. by more than 10 deg. cent.

(*b*) The resistance of a wire of industrial copper one meter long and of one sq. mm. cross-section, increases 0.000068 ohm per deg. cent.

(*c*) The resistance of a wire of industrial copper one meter long and of one gm. mass, increases 0.00060 ohm per deg. cent.

(*d*) The density of industrial annealed copper at 20 deg. cent. should be taken as 8.89 gm. per cu. cm.

This value of the density should always be employed in the computation of conductivity in percentage of that of the annealed copper standard.

It follows from the above that if R is the resistance in ohms, at t deg. cent. of a wire having a length of l meters and a mass

of *m* grams, the resistance of a wire of the same copper one meter long and one sq. mm. cross-section will be

$Rm/\ (l^2 \times 8.89)$ ohms at t deg. cent. and
$Rm/\ (l^2 \times 8.89) + 0.000068\ (20 - t)$ ohms at 20 deg. cent.

The percentage conductivity of this copper is thus

$$100 \times \frac{0.01724}{\dfrac{Rm}{l^2 \times 8.89} + 0.000068\ (20 - t)}$$

Similarly, the resistance of a wire of the same copper one meter long and one gm. in weight is

Rm/l^2 ohms at t deg. cent., and
$Rm/l^2 + 0.00060\ (20 - t)$ ohms at 20 deg. cent.

The percentage conductivity is thus:

$$100 \times \frac{0.1533}{\dfrac{Rm}{l^2} + 0.00060\ (20 - t)}$$

NOTE 1. The standard values given in (I) are mean values deduced from a large number of tests. Among a number of samples of copper of normal conductivity, the density may differ from normal density up to 0.5 of one per cent, and the temperature coefficient of resistivity may differ from the normal up to one per cent; but between the limits indicated in (II) these deviations will not affect the values of the computed percentage conductivity, if the resulting values are limited to four significant digits.

NOTE 2. The values above stated correspond to the following physical constants for standard annealed copper, all at the temperature of 0 deg. cent.

Density, 8.90 gm. per cu. cm.

Coefficient of linear expansion 0.000017 per deg. cent.

Resistivity, 1.5879* microhm-cm.

Volume resistivity temperature-coefficient 0.00429* per deg. cent. from and at 0 deg. cent.

Resistance temperature coefficient at constant mass, 0.00427 $= 1/\ 234.5$ per deg. cent. from and at 0 deg. cent.

*These two numerical values will probably be changed to 1.5880 and 0.00428 by the National Physical Laboratories. Since reference is made exclusively to the values at 20 deg. cent. when measuring and stating percentage conductivity, these physical constants for 0 deg. cent. are of secondary importance in engineering.

A paper presented at the San Francisco Section of the American Institute of Electrical Engineers, February 28, 1913, and at the Los Angeles Section, April 22, 1913.

(Subject to final revision for the Transactions.)

OPERATION OF TRANSMISSION LINES

BY LEE HAGOOD

This paper will deal with controlling voltage and power factor in transmission lines by means of synchronous machines. The first part will relate to moderate voltage systems having small charging currents but large inductive loads, and the second part to systems having high-voltage transmission lines in which the charging current is considerable. The underlying principles are substantially the same in both cases.

SYSTEMS OPERATING AT MODERATE VOLTAGES

Where the transmission line is short and the voltage is 60,000 volts or below, the charging current is so small that it may be neglected so far as voltage or power factor is concerned.

Fig. 1 represents a transmission line and Fig. 2 a vector diagram illustrating the relation between generator voltage and receiver voltage for an inductive load. *

It is assumed that the current, voltage and power factor are measured at the load end of the line. The actual current, I, lags behind the receiver voltage by the angle θ whose cosine is the power factor; it causes a drop through the resistance, R, in phase with it, *i.e.*, IR can be drawn parallel to I; and causes a drop through the reactance 90 deg. out of phase with I, the current lagging with respect to IX, *i.e.*, IX may be drawn at right angles to I in the direction indicated. The vector E_G represents the required voltage at the generator end of the line.

*In complex quantities $E_2 - E_1 = I_0 Z$ since $Y = 0$, where $I_0 = i_1 + j i_2$ and $Z = r - jx$. Hence $E_2 - E_1 = i_1 r + i_2 x + j\,(i_2 r - i_1 x)$. The imaginary quantity effects the result so slightly that it may be neglected, especially when the power factor is lagging. See Dr. Steinmetz's formulas, page 2176.

By an inspection of Fig. 2, the following is evident:

$$V = E_G - E_R = AD = AB + BC + CD$$
$$AB = IR\cos\theta = I_eR$$
$$BC = IX\sin\theta = I_wX$$
$$CD = E_G - E_G\cos x = E_G(1 - \cos x)$$

Then $V = I_eR + I_wX$ (Approximately)

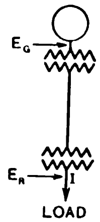


FIG. 1

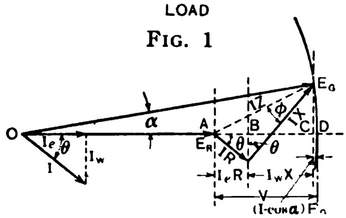


FIG. 2—VECTOR DIAGRAM OF A TRANSMISSION LINE SHOWING RELATION BETWEEN GENERATOR AND RECEIVER VOLTAGE.

E_G = Generator voltage.
E_R = Receiver volts.
V = Voltage drop.
I = Receiver current.
I_e = Energy component of I.
I_w = Wattless component of I.
R = Resistance between E_G and E_R.
X = Reactance between E_G and E_R.
θ = Angle whose cosine is the power factor.
ϕ = Angle whose tangent is R/X.
α = Angle between E_G and E_R.

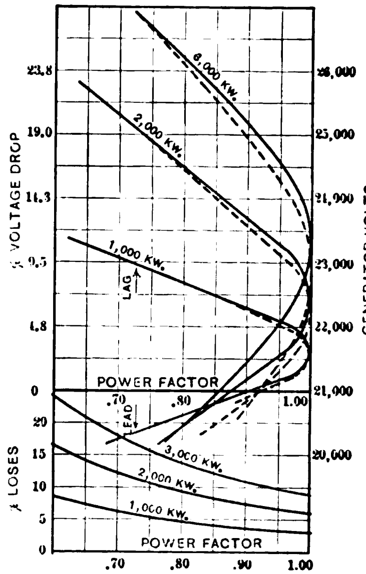


FIG. 3—RELATION OF GENERATOR VOLTAGE TO RECEIVER VOLTAGE FOR DIFFERENT LOADS AND POWER FACTORS FOR A CONSTANT RECEIVING VOLTAGE OF 21,000 VOLTS.

The dotted curves are calculated using the approximate formula.* For the constants of the line and transformers refer to Table III and Fig. 7.

* The error in using the approximate formula decreases with lagging power factors, with a decrease in ratio of X to R and with a decrease in kilowatts. For a transmission line itself under normal conditions this formula is quite accurate. See Table I, page 2175.

The quantity $E_G(1 - \cos\alpha)$ is so small that it may be neglected. In dropping this quantity the maximum error is about 2 per cent for the usual conditions that arise in practise, which precision is below the requirements of the present problem. This gives us a very simple and convenient formula for voltage drop, viz. $V = I_eR \pm I_wX$, the plus sign should be used if the

current is lagging with respect to the receiver volts and the negative sign if leading.

Fig. 3 illustrates the effect of power factor on voltage drop in transmitting power. It is assumed that the generator voltage is varied in such a manner as to maintain constant voltage at the receiving end of the line. For simplifying the problem equivalent high tension voltages and resistance are used. These curves represent a condition where the ratio of resistance to reactance is 0.42, this ratio being tangent ϕ. (See Fig. 2.) Had this ratio been greater, the curves would have been steeper. The dotted curve shows the calculations using the approximate formula, while the full line is accurately calculated.

It is thus seen that when the reactance in a transmission circuit is of any magnitude, the effect of the wattless current on

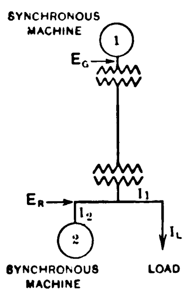


FIG. 4

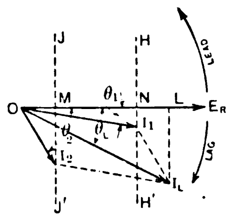


FIG. 5—CURRENT AND POWER FACTOR RELATION OF TWO ALTERNATORS IN PARALLEL.

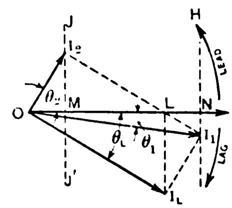


FIG. 6—CURRENT AND POWER FACTOR RELATIONS FOR AN ALTERNATOR IN PARALLEL WITH A SYNCHRONOUS MOTOR

voltage drop is considerable. With a synchronous machine on the receiver end of the line, we can control this wattless current and therefore regulate the voltage difference. For this method of control considerable reactance in the circuits involved is a desirable quality.

PHASE OR POWER FACTOR CONTROL

Fig. 4 is a one-line diagram of a simple transmission system and Fig. 5 is a vector diagram of the phase relations, assuming both machines No. 1 and No. 2 to be synchronous generators, while Fig. 6 illustrates the phase relations assuming machine No. 1 to be a generator and machine No. 2 to be a motor.

Referring to Fig. 5, OL to scale is the kilowatts supplied the load and is equal to ON plus OM which are the outputs of generators No. 1 and No. 2 respectively. The division of load

between these generators, as with all synchronous generators in parallel, is entirely a question of prime movers; proper division of load may be obtained automatically by means of governors, or non-automatically by hand control of the throttle or water gate, depending upon whether the prime mover in question is a steam engine or water wheel. In a similar manner the wattless current, or wattless kv-a. of the load is the algebraic sum of that supplied by the generators and its division between them is entirely a matter of relative field excitation; suitable division of the load's wattless kv-a. may be obtained automatically by means of voltage regulators, or non-automatically, by hand control of their field rheostats. If the excitation of generator No. 2 is increased, I_2 will increase but the terminal of this vector necessarily* moves in the locus JJ' because the energy component is unaffected, since division of load can only be changed by adjusting the relative inputs of the prime movers; to satisfy the new position of I_2, I_1 must move to a position where I_L is the vectoral sum of I_1 and I_2; thus by changing the excitation of generator No. 2, we can change at will the power factor or phase, of the transmission line.

In Fig. 6, it is assumed that synchronous machine No. 1 is a generator and No. 2 a motor. $O\,N$ represents the generator output and this equals $O\,M$ plus $O\,L$, the kilowatts required by the motor and load respectively. In this case again the wattless current, or wattless kv-a. of the load is equal to the algebraic sum of the wattless kv-a's. supplied by the synchronous machines. By varying the excitation of the motor the power factor or phase, of the transmission line may be varied at will.

Whether machine No. 2 is a motor or generator, raising its excitation raises the voltage of its busbars, and vice versa. When, for example, we raise the excitation of machine No. 2, we raise the flux and therefore the internal generated e.m.f. and this produces a change in the idle wattless current between the machines, the reaction of which in the armature of No. 1 is equivalent to an increase in field excitation on No. 1. The reaction caused by any tendency towards a new voltage condition on a system, therefore, is a mutual one; the machine

*This statement neglects the fact that any changes in voltage will tend to change the load on the system, since the power consumption of lamps, etc., depends upon the square of the applied voltage. Any change in load on a system simply tends to change the frequency, which in turn actuates the governors on the prime movers, dividing the load according to their individual speed characteristics.

whose excitation is raised suffers a change in its power factor so that an armature reaction occurs, tending to demagnetize its fields, while the other synchronous machines react by changing their power factors, tending to magnetize their fields; the system will thus acquire a new voltage, exciting current being furnished by the machine on which we attempted to raise the voltage to the other synchronous machines in the system. This mutual reaction between synchronous machines occurs whenever the voltage balance between them is disturbed. The magnitude of these phenomena depends mainly upon the number and sizes of the synchronous machines on the system and the resistance and reactance in the circuits involved.

If we should take any single machine and control its excitation automatically with a voltage regulator, holding the voltage constant, the power factor of this machine, as well as those in parallel with it, would vary through certain limits, tending to preserve the voltage at this point in spite of variations in load, tending to destroy it.

Automatic Voltage Regulation

Referring to Fig. 7, we could apply a voltage regulator to either machine No. 1 or machine No. 2 or to both. To make the analysis of this problem simple, it will be assumed that voltage regulators are applied to both machines, and that machine No. 2 is a synchronous condenser. A synchronous condenser is a specially designed synchronous motor for operating without energy load from minimum current to full kv-a. As the maximum losses are quite small, in the magnitude of 4 per cent of the kv-a. rating of the synchronous condenser, their consideration for the present will be neglected.

Since the voltage drop is constant the wattless current, I_W, which must be maintained in the transmission line at the receiver end for different loads, can be obtained from the following equation:

$$I_W = \frac{V - I_e R}{X}$$

and the energy component of the current (for a three-phase circuit) is

$$I_e = \frac{\text{kilowatts}}{E_R \times 1.73}$$

The actual current at the receiving end of the line is therefore

$$I = \sqrt{I_e^2 + I_w^2}$$

and the actual power factor at the receiving end of the line is

$$\cos\theta = I_e/I$$

All of these quantities have been plotted in Fig. 8 for a given condition of voltage drop and resistance and reactance.

To obtain the synchronous condenser current, which is substantially wattless, we first determine the wattless current of the load, viz:

$$I_{WL} = I_e \tan\theta_L$$

and the synchronous condenser current will be

$$I_S = I_{WL} \mp I_W$$

The minus sign should be used if I_W is lagging and the plus sign if it is leading. Fig. 9 gives two sets of synchronous condenser curves, one assuming the load to have a constant power factor of 0.8 and the other of 0.6.

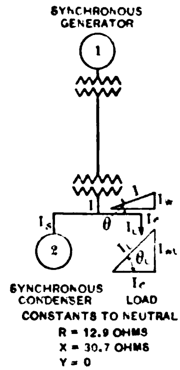


FIG. 7

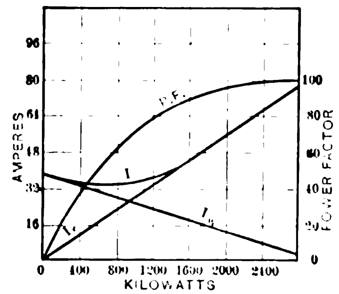


FIG. 8—ILLUSTRATES RELATION OF CURRENT, ITS ENERGY AND WATTLESS COMPONENT, TO THE KILOWATTS FOR CONSTANT VOLTAGE DROP

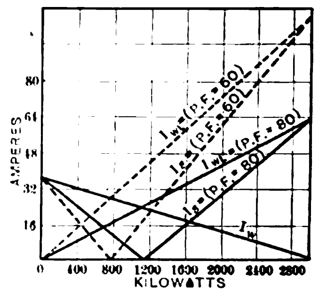
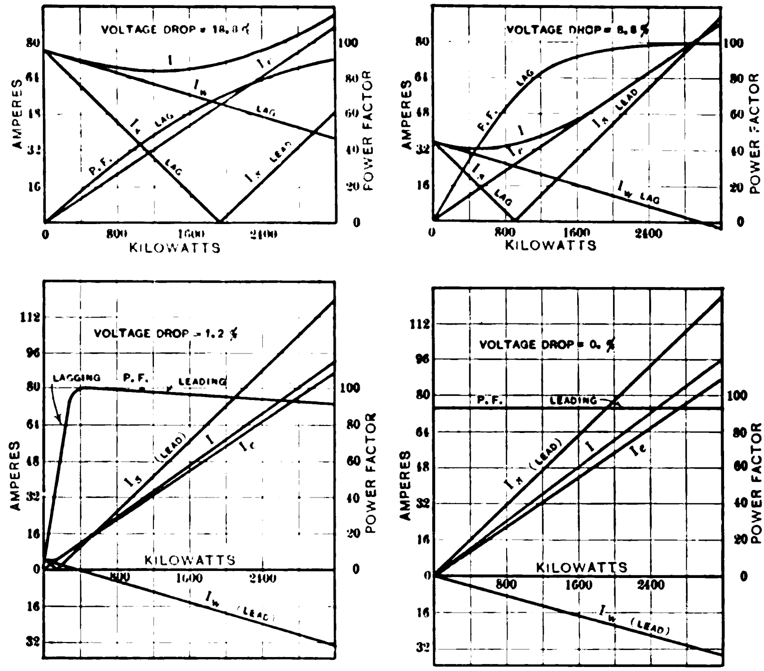


FIG. 9—ILLUSTRATES THE WATTLESS CURRENT FROM A SYNCHRONOUS MACHINE TO MAINTAIN CONSTANT VOLTAGE DROP. TWO CONDITIONS OF LOAD ARE ASSUMED; ONE AT 0.6 AND THE OTHER AT 0.8 POWER FACTOR.

Figs. 10, 11, 12 and 13 illustrate the effect of maintaining different voltage differences between the generating and receiving ends of a certain transmission line. The values of voltage drops are taken at 18.8, 8.8, 1.2 and 0 per cent. It may be noted that the power factor appears to approach some constant value for all loads as the voltage difference becomes small. This

condition occurs when the line I_e intersects I_w at the origin, which is the condition of zero voltage difference, if the capacity current is negligible. The value of the power factor under this condition approaches unity as the ratio of R to X increases, this ratio being the tangent of angle ϕ. These data apply to the transmission line illustrated in Fig. 7. It is a three-phase, 22,000-



FIGS. 10, 11, 12 AND 13—SHOW THE RELATIONS FOR VOLTAGE DROPS* OF 18.8, 8.8, 1.2 AND 0 PER CENT, RESPECTIVELY, FOR THE SYSTEM IN FIG. 7.

The equivalent high-tension resistance and reactance to neutral are 12.9 and 30.7 ohms, respectively. The equivalent high tension receiving voltage is 21,000 volts. The synchronous condenser current is based on a load of 0.7 power factor.

*Calculated by the approximate method, the accuracy of which is within the limits of practical requirements. For accurate calculations the method illustrated in Figs. 18, 19 and 20 may be used.

volt, 60-cycle line, 12.7 miles (20.37 km.) long, consisting of three No. 2 copper conductors spaced 30 in. (76.2 cm.). The resistance and reactance given are phase to phase values, and include the transformers.

Evidently, if the voltage established at the receiving end of a transmission line is such that the voltage drop is small, the

voltage being controlled by a synchronous machine with a voltage regulator, there is no necessity in some cases for a voltage regulator at the generating station. It becomes practical, therefore, to operate a system* by controlling the voltage at the distribution centers by means of synchronous condensers with voltage regulators without using voltage regulators on any of the generators.

Controlling the voltage at the receiving ends of transmission lines by governing the wattless current so as to operate the lines with small voltage drops, not only brings about highly satisfactory service on account of the excellent voltage regulation, but makes the operation of the system very flexible. Since the power factor in the transmission line and its transformers and generators is above 0.9 except at light loads, the waterwheels, or steam units, as the case may be, can operate at all times at efficient points of their load curves without any limit being encountered due to transformers, generator and transmission line capacity such as might occur if the power factor were low. Since the copper losses vary inversely as the square of the power factor for a given load, considerable net saving may be accomplished by correcting the power factor, although losses occur in the synchronous machines effecting the correction. Another advantage that comes from operating a system in this manner is that the small voltage drops avoid to some extent the necessity for transformer taps. But most important of all seems to be that considerable reactance may be used in the generators, transformers and transmission lines, and this makes the problem of switching a simple one, since the destructive effects of short circuits may be largely eliminated.

HIGH-VOLTAGE TRANSMISSION SYSTEMS

In the transmission of power over a long high-voltage line, say for voltages of 60,000 volts and higher, the exciting or wattless currents which must be provided are not only those for the induction motors, transformers, etc., but whatever is required by the transmission line itself. A transmission line has both inductance and capacity, both of which require exciting current. The leading current required by the capacity is of very much greater magnitude than the lagging current required by the in-

*For a description of a system so operated see the author's article in the *General Electric Review* for December, 1912, entitled "Operation of Synchronous Machines in Parallel."

ductance, hence the exciting current to charge a transmission line is always leading, that is with reference to the generators. To charge a line by means of a synchronous motor requires lagging current. On some of the 110,000-volt lines, as much as 10,000 kv-a. is required to charge a single line under normal voltage conditions. Even considerably more than this is necessary for 140,000-volt lines.

It may appear that a happy solution of the voltage and power factor problem arises if the exciting currents caused by an induction motor load just offset the charging current of the transmission line. The difficulty arises in such a case that the number of induction motors in operation is under the control of customers and is therefore a variable quantity, whereas the charging current is fixed by the voltage and constants of the line; furthermore, other loads such as railway, lighting, etc., have their variations: hence, to maintain suitable voltage at the receiving end of a transmission line requires in general that the generating voltage be varied through large limits. In many stations the characteristic load is such that for different periods of a day the necessary generator voltage can be foretold; if the lines are short the operators can often adjust successfully the field currents to meet the demands at the receiver end, or the field current may be controlled automatically. But this method of control may be totally inadequate for long high-voltage lines.

Voltage Regulation Limitations

In the design of a transmission system, the voltage regulation must be within such limits on all parts of the system that satisfactory service is secured and, at the same time, all the transformers obtain proper exciting voltages and the lightning arresters be exposed to only safe dynamic voltages.

Service for lighting loads is very exacting, since a 2 per cent variation in voltage causes a change of approximately 8 per cent in candle power. Service for power loads is not so exacting; nevertheless, it is of considerable importance, because on reduced voltage the starting torque and maximum horse power of induction motors fall off as the square of the voltage. Since the power consumed by any load falls off approximately as the square of the voltage, it is of great importance to power companies that the voltage be maintained as high as consistent with satisfactory service.

Transformers should have proper exciting voltage, because in general, a departure from normal rated voltage reduces the capacity for a given heating rise. By exciting voltage is meant the voltage applied on the side from whence the power comes. Reducing the voltage by a given per cent reduces the kv-a. capacity substantially by the same per cent, since the ampere capacity depends on the size of conductors. Increasing the voltage above normal decreases the output, because the exciting current is increased and also the core losses. Just how much increased losses occur for a given over-voltage depends upon characteristics in design, but it is safe practise, in general, never to exceed say 5 per cent of the rated voltage.

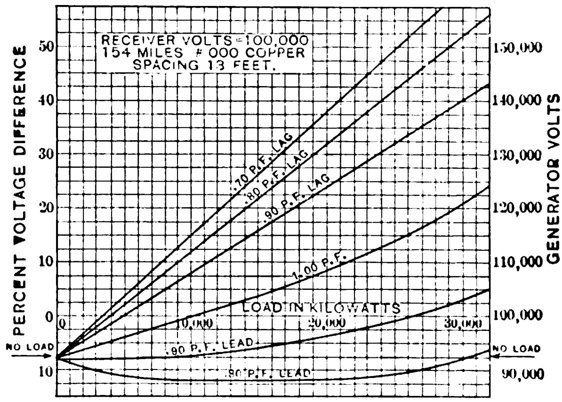


FIG. 14—SHOWS THE GENERATOR VOLTAGES TO MAINTAIN A RECEIVER VOLTAGE OF 100,000 VOLTS FOR DIFFERENT POWER FACTORS AND KILOWATTS. THE TRANSFORMER CONSTANTS ARE INCLUDED

To prevent lightning arresters from being endangered by overvoltage, they should not be exposed to a voltage regulation exceeding 15 or 20 per cent. Lightning arresters are designed to protect against transient voltages, and their characteristics are such that they offer protection only around the normal voltage rating. Should a lightning arrester be called upon to relieve a transient voltage, when the dynamic or steady voltage of the system was 15 or 20 per cent above that at which the lightning arrester was charged, it would be exposed to serious damage, on account of the large flow of current occurring. Hence, it is not considered safe practise to expose a lightning arrester equipment to a voltage regulation exceeding 15 or 20 per cent.

Effect of Power Factor at Receiver on Voltage Drop

Figs. 14 and 15 illustrate the effect of voltage drop for different loads and power factors, while Fig. 16 shows the system to which the data apply. In Fig. 14 the ordinates represent the kilowatts supplied the receiver and the abscissas the voltages at the generators. Equivalent high-tension values of voltage are used, the per cent difference being between the generator and receiver low-tension busbars, since the transformer reactance has been included in the calculation. For example, if 20,000 kw. at 0.8 power factor were required by the receiver at 100,000 volts, the generator voltage would have to be 132,000 volts, or 32 per cent above the receiver volts, and at no-load, to maintain the same receiver volts, the generator volts would have to be 93,000 volts, or 7 per cent below the receiver volts, causing a total range at the generating station of 39 per cent. This is, of course, an operating condition impracticable to meet. Fig. 15 gives a set of curves where the generator voltage is plotted against power factor. For example, suppose 20,000 kw. were to be received at 100,000 volts, the curve for this load shows the different voltages that would be required at the generating station for different power factors at the receiver.

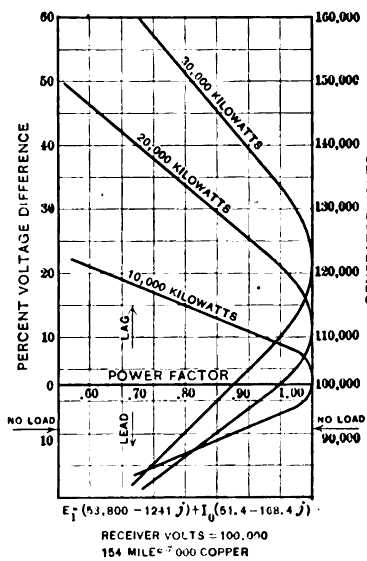


Fig. 15—Illustrates the Generator Voltages for Different Kilowatts to Maintain a Receiver Voltage of 100,000 Volts, Assuming the Power Factor of the Receiver at Different Values.

For a given set of conditions on a long transmission line, the power factor varies at different points along the line due to the effect of the distributed capacity. The only points which need be considered are the generator and receiver ends of the line, since the power factors here determine the kv-a. capacities of the generators and transformers. As will be seen below, the power factors at these points for a given transmission line depend upon the voltage difference.

Constant Voltage Drop

As with the lines previously considered, having negligible charging current, as soon as the voltage is fixed at two points, fixed conditions of power factor are established from no load to full load, independently of the power factor of the load.

Fig. 16 is a one-line diagram of a system. The transmission line is 154 miles long, the conductors being No. 000 copper spaced 10 feet in a vertical plane which is equivalent to 13 ft. (3.96 m.) equilaterally. The constants to neutral are, resistance 53.9 ohms. reactance 171 ohms and shunted admittance 0.0008 mhos. The transformer resistance and reactance are included.

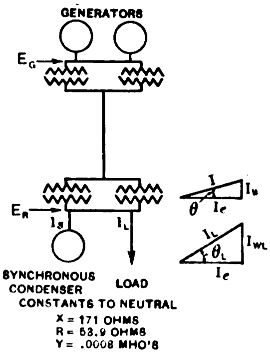


Fig. 16—(The Characteristics of this Line are given in Col. 2, Table I.)

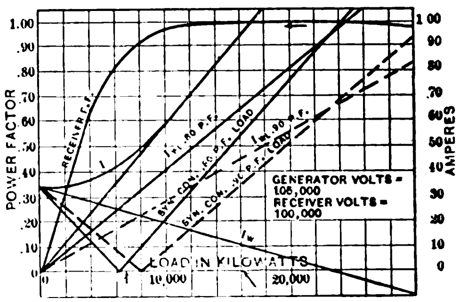


Fig. 17—Shows the Approximate Relations for a Constant Voltage Drop of 5 per cent for the Line in Fig. 16.

It will be assumed that this line is to be operated at 5 per cent voltage drop, constant voltage being maintained by voltage regulators on the generators and synchronous condenser.

As it will simplify the problem, first the approximate relations will be established and then the same general results obtained accurately.

The following approximate formula applies for voltage drop, as follows:

$$V = I_e R + I_w X - I_c X/2$$

This formula is a modification of that already given to include the charging current I_c. Since the capacity is distributed

TABLE I

Length of line in miles	12.74		153.4		153.4		127		275		275	
Size of conductor	No. 2 Copper		3/0 Copper		3/0 Copper		5/0 Aluminum		605,000 cir. mil.		605,000 cir. mil.	
Equilateral spacing, feet	2.5		13		13		13		14		14	
Line constants to neutral	Z = 10.5-8.8j		Z = 50-127j		Z = 50-127j		Z = 41.4-100j		Z = 41.4-171j		Z = 41.4-171j	
	Y = 0		Y = -0.0008j		Y = -0.008j		Y = -0.006930j		Y = -0.00132j		Y = -0.00132j	
Transformer constants to neutral	Z = 2.5-21.8j		Z = 3.9-44j		Z = 0		Z = 0		Z = 0		Z = 0	
	Y = 0		Y = 0		Y = 0		Y = 0		Y = 0		Y = 0	
Load in kw	2,000		20,000		20,000		20,000		20,000		50,000	
Voltage at receiver	21,000		100,000		100,000		100,000		140,000		140,000	
Power factor at receiver	1.00	0.80	1.00	0.80	1.00	0.80	1.00	0.80	1.00	0.85	1.00	0.85
Generator voltage (accurate)	22,400	24,500	109,100	132,000	108,000	124,500	106,800	120,000	132,000	146,000	140,000	182,000
Generator voltage (approximately)	22,200	24,400	103,900	129,500	105,000	123,800	105,200	119,600	130,000	146,500	139,000	176,500
Per cent error	0.8	0.4	4.8	1.9	2.8	0.6	1.5	0.3	1.5	0.3	0.7	3.0

The above table gives the characteristics of the various transmission lines referred to in the text. As a matter of interest acomparison is shown to illustrate the accuracy of the approximate formula on page 2174. The error is quite small except in column 2, where the constants of the transformer were included.

along the line, we can assume that the voltage drop is approximately $I_c X/2$. The actual wattless current in the receiver end of the line is I_w. For most conditions this formula will be accurate within a few per cent. Table 1 gives an idea as to the limitations of its use.

Fig. 17 shows a set of curves similar to those in Figs. 8 and 9. For simplicity it is assumed that the synchronous condenser losses are negligible. The current required by the synchronous condenser will depend upon I_w, the amount of wattless current which must be maintained in the receiver end of the line for a given voltage difference, and upon the load's wattless current I_{wL}. For the sake of comparison two conditions of load are assumed, one at 0.8 power factor and another at 0.9 power factor. The actual current at the receiver end of the line is, of course, independent of the load's power factor but depends upon the voltage difference maintained and the kilowatts delivered.

Results obtained in the above manner are accurate enough for a preliminary examination of a problem, but for important calculations greater accuracy is necessary. Dr. Steinmetz has made possible a very simple solution of the problem by the following formulas*, viz:

$$E_1 = E_0\,(1 + ZY/2) + I_0 Z\,(1 + ZY/6).$$
$$I_1 = I_0\,(1 + ZY/2) + E_0 Y\,(1 + ZY/6).$$

These equations involve complex quantities; E_1 and I_1, and E_0 and I_0 represent the voltage and current at the generator and receiver ends respectively, while Z and Y are the impedance and shunted admittance between the points in question.

Thus, by knowing the constants of a line and assuming the voltage, kilowatts and power factor at the receiving end, the voltage, kilowatts and power factor of the generating end can be determined as well as the efficiency of transmission. Fortunately it works out here, as with those lines where the charging current is negligible, that for a given voltage difference, the relation of wattless current, or wattless kv-a. in the receiver end of the line has a straight line relation with the kilowatts.

Fig. 20 is a set of curves similar to those in Fig. 17. The

*For a solution of a problem with these formulas see article by F. W. Peek in the June 1913 number of the *General Electric Review* entitled "Practical Calculations of Long Distance Transmission Line Characteristics."

voltage difference and line constants are the same. Since the line "Receiver Wattless kv-a." in Fig. 20 has a straight line relation with the kilowatts, only two points are necessary for its location. It is convenient to locate one point by the amount of wattless lagging kv-a. in the receiving end of the line which will give the specified voltage drop at zero load. Fig 18 is a curve from which the information may be obtained, it being 8,500 wattless lagging kv-a. for a voltage drop of 5 per cent. Another convenient point is where the kilowatts transmitted is at unity power factor, that is where the "Receiver Wattless kv-a." is zero, gives the same voltage drop. Fig. 19 is the curve from which this information may be obtained, it being 13,000 kw. at unity power factor for a 5 per cent voltage drop. Thus the line "Receiver Wattless kv-a." can be established and from it the receiver kv-a. and power factor as well as the synchronous condenser kv-a., for different values of kilowatts. To determine the kilowatts and power factor at the generator end involves the use of the complex equations. It will be found that the voltages calculated will check up with the assumption that for a given voltage difference the wattless kv-a. in the receiver end of a line has a straight line relation with the kilowatts.

Fig. 21 gives the values of voltage at which the generators must operate, if no synchronous condensers are used and a voltage of 100,000 volts is to be maintained for a load of 0.8 power factor. The efficiency of transmission and the generator power factor is also given. It would not be very satisfactory to operate the generators at voltages higher than about 15 per cent above the receiver, since this would involve a total range in voltage at the generator station of about 23 per cent. A maximum load about 12,000 kw. at 0.8 power factor could be carried with a 15 per cent drop. As may be seen from Fig. 20, 30,000 kw. could be delivered over the same line with better efficiency and better power factor with a constant voltage drop from no-load to full load of 5 per cent.

Operating a system at small voltage drops in transmission would offer the advantage that all the transformers could be standardized for one voltage and the troublesome question of transformer taps could be avoided. The wattless corrective kv-a. to control the power factor of a transmission line and hence its voltage need not all be under automatic control, but just so much as is necessary to control any tendency towards voltage changes. In the case cited, all the power was taken off the end

of the line, and the wattless corrective kv-a. was applied at that point. As matter of fact the load could be applied at several points along the line, and synchronous machines used at these points to control the voltage. Some of the synchronous machines could be in the secondary distribution at very remote points from the main transmission line; in fact, the further away the better, since the power factor correction would improve the condition in the circuit in question as well as in the main transmission line. It is thus possible to operate an entire system with

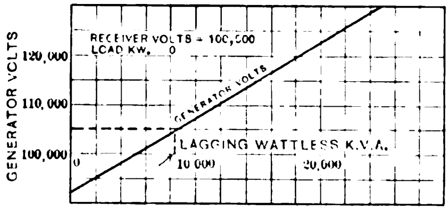


Fig. 18.—Generator Volts to Maintain Receiver Voltage of 100,000 for Zero Kilowatts and Different Amounts of Wattless Kv-a. at the Receiver

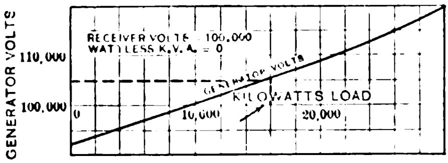


Fig. 19.—Generator Volts to Maintain Receiver Voltage of 100,000 for Zero Wattless Kv-a. and Different Amounts of Kilowatts at the Receiver: that is, the Power Factor at the Receiver End is Assumed at 1.00 for all Loads.

voltage drops of little consequence; in fact, the voltage of any system can be controlled entirely by means of synchronous condensers with voltage regulators located at the principal centers of distribution without using voltage regulators on the generators.

In Fig. 20, the voltage drop was taken at 5 per cent. By making the difference greater, a smaller amount of wattless corrective kv-a. would be required. However, the voltage difference should not exceed a certain amount depending upon the constants of the transmission line, otherwise too much lagging current would be required at light loads.

Generator Voltage Varied With Load To Supply Constant Receiver Voltage

To meet the requirements of high efficiency and favorable use of the available kv-a. of the generator and transformer capacities, the voltage drop can be increased as the load comes on. This may be done in such a manner as to make maximum use

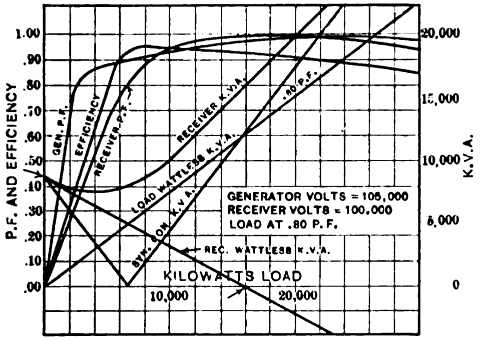


Fig. 20—Shows the Accurate Relations for a Constant Voltage Drop of 5 Per Cent for the Line in Fig. 16

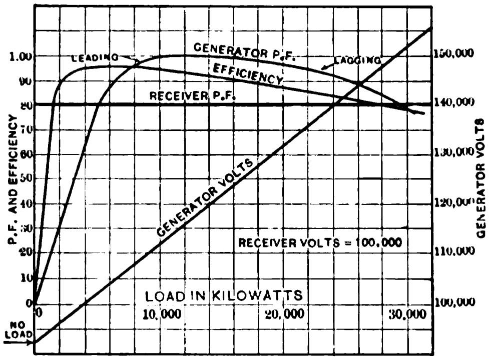


Fig. 21—Shows the Relations if the Voltage Drop is not Controlled for the Line in Fig. 16

of a given number of synchronous condensers with voltage regulators.

A concrete example of design will be given to illustrate the practical value of this application: Assume a transmission system consisting of two lines 127 miles (38.7 km.) long, each having three steel reinforced aluminum conductors spaced 10 ft.

(3 m.) in a vertical plane, and two synchronous condensers normally rated at 5000 kv-a. located at the receiver end of the line. It will be assumed that 42,000 kw. is the maximum output of the generating station and this is to be applied normally over two

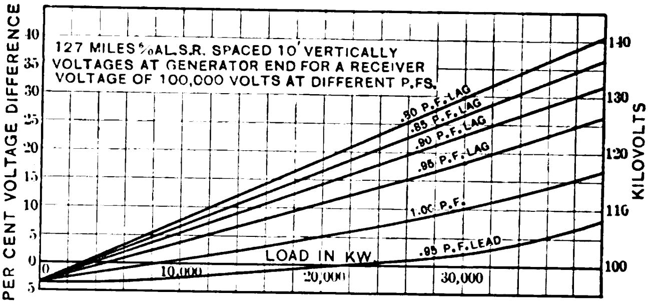


FIG. 22.—TRANSMISSION LINE REGULATION. CONSTANTS OF TRANSFORMERS NOT INCLUDED. SIZE OF CONDUCTOR 6/0 ALUMINUM

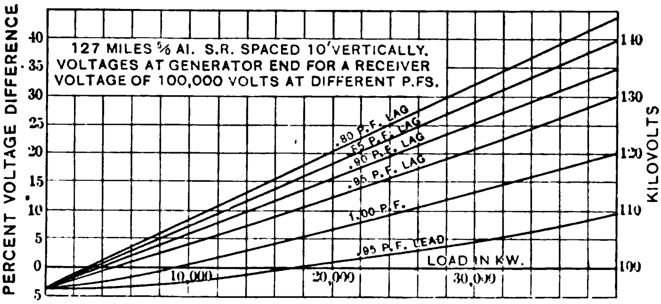


FIG. 23.—SAME AS FIG. 22 EXCEPT THE CONDUCTOR IS 5/0 ALUMINUM

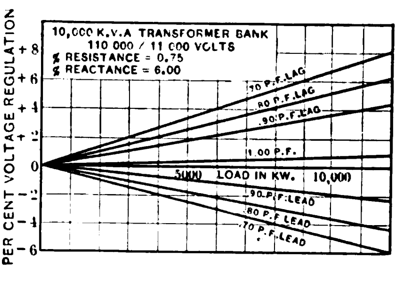


FIG. 24—VOLTAGE REGULATION OF A 10,000-KV-A. TRANSFORMER

lines, but in case of trouble, one line must carry the entire output. Since the nature of the use of the synchronous condensers involves their operation on rather poor load factors, the 25 per cent overload rating will be used in the calculation. The actual

energy consumed by each synchronous condenser will be about 200 kw. at its full kv-a. load. It will be assumed also that four 10,000-kv-a. banks of transformers are located at both the generating and receiving ends of the line.

It will simplify the problem, as well as lend to greater accuracy,

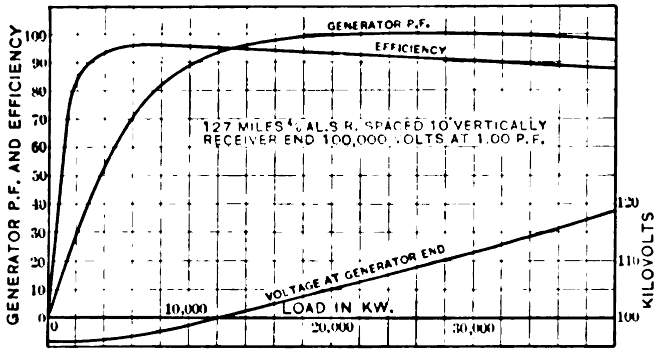


Fig. 25.—Relations at Generator End of Line for an Assumed Receiver Voltage of 100,000 and Power Factor of 1.00. Transformer Constants Included at Generator End only. Size of Conductor 6/0 Aluminum.

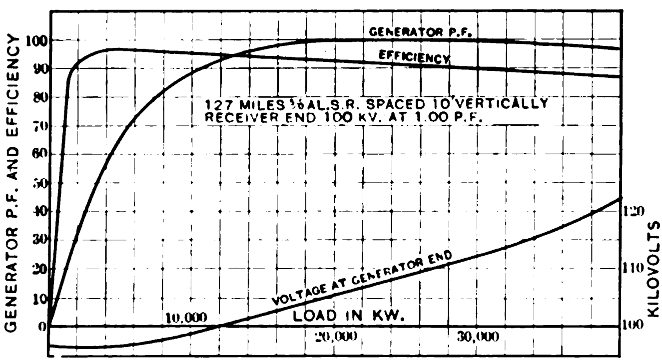


Fig. 26.—Same as Fig. 25 Except the Conductor is 5/0 Aluminum

if the transmission line is considered separately from the transformers. A slight error would occur if the transformers and line were treated as one, because the capacity of the line is distributed.

What little capacity occurs in the transformer itself may be neglected. Hence the calculations below are given for the line and transformer separately. Since the spacing of conductors

is considerable for the higher voltages, the reactance introduced thereby is great. Increasing the size of conductors therefore will help but slightly in the matter of voltage regulation. Figs. 22 and 23 afford a comparison between 6/0 and 5/0 steel reinforced aluminum conductors. Fig. 24 is a set of curves to illustrate the regulation at different power factors for any one of the transformer banks.

Since the power factor is to be kept near unity at the receiving end by means of the synchronous condensers, not sufficient advantage would be gained by using the larger conductor to justify the extra expense. A comparison of the two sizes of conductors for unity power factor in the receiving end is afforded in Figs. 25 and 26.

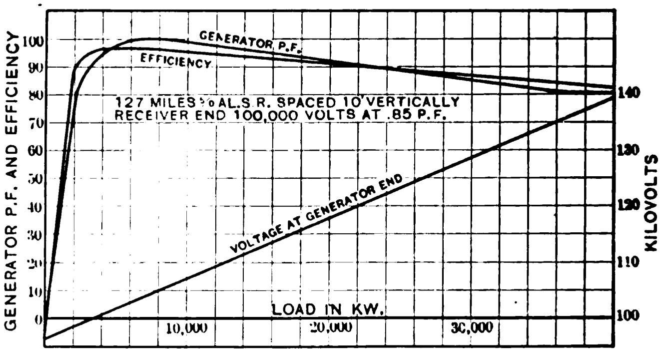


FIG. 27.—SAME AS FIG. 26 EXCEPT THE RECEIVER POWER FACTOR IS 0.85 AND NO TRANSFORMER CONSTANTS ARE INCLUDED

To bring out the advantages of the synchronous condensers, a set of calculations will be made with and without, assuming the load to be 0.85 power factor. Since the cost of high-tension equipment increases considerably with voltage, the comparison will be made on the basis of approximately the same generator voltage. To simplify the calculation, the effect of the transformers will be neglected, as this will not injure the accuracy of the comparison to any marked extent.

WITHOUT SYNCHRONOUS CONDENSERS

Refer to Fig. 27 and to Table II. With both lines in parallel a load of 38,600 kw. at 0.85 power factor and 100,000 volts can be carried at an efficiency of 92 per cent, which would re-

quire at the generating end 42,000 kw. at 0.93 power factor (45,000 kv-a.) and a voltage of 117,000 volts; the control of voltage at the generating end of the line would have to be from 96,000 to 117,000 volts, a range of 21 per cent, if a constant voltage of 100,000 volts be maintained at the receiving end of the line.

With only one line, a load of 35,600 kw. at 0.85 power factor and 100,000 volts could be carried at an efficiency of 85 per cent which would require at the generating end of the line 42,000 kw. at 0.83 power factor (50,600 kv-a.) at a voltage of 135,000 volts. The control of voltage at the generating station would have to

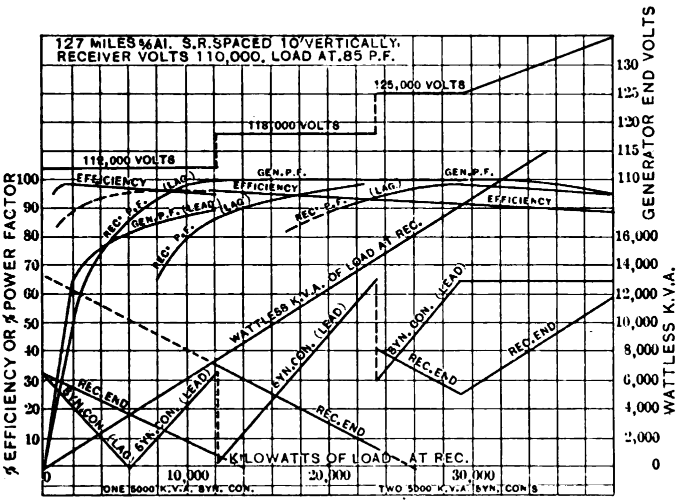


FIG. 28—ILLUSTRATES THE RELATIONS OF TRANSMISSION EFFICIENCY, POWER FACTOR AT EACH END OF A LINE AND SYNCHRONOUS CONDENSER KV-A. FOR VOLTAGE DROPS OF 1. 7, 7.3 AND 13.6 PER CENT, RESPECTIVELY, FOR A LOAD FROM 0 TO 30,000 KW. AT 0.85 POWER FACTOR. NO TRANSFORMER CONSTANTS INCLUDED.

be from 96,000 to 135,000 volts, a range of 41 per cent, if a constant voltage of 100,000 volts at the receiving end is maintained.

WITH SYNCHRONOUS CONDENSERS

Refer to Fig. 28 and Table III. Fig. 28 illustrates the effect of varying the voltage difference in order to increase the voltage range of operation of the synchronous condenser: whenever the voltage drop is changed the synchronous condenser will automatically take a new point in operation on its phase curve. It is assumed in this case that voltage regulators are used on the machines at both ends of the line.

TABLE II

Receiver end of line			Load	Generator end of line				Transmission line	
Kv-a.	Kw.	Power factor	Power factor	Voltage	Kw.	Kv-a.	Power factor	Efficiency	Volts difference
0	0	0.0	0.0	96,600	170	6,600	0.026 lead	0.0	3.4% rise
7,300	6,200	0.85	0.85	103,000	6,460	6,520	0.99 "	96.0	3.0% drop
14,400	12,200	0.85	0.85	109,500	12,900	13,200	0.978 lag	94.7	9.5% "
29,200	24,000	0.85	0.85	122,000	26,700	29,600	0.90 "	90.0	22.0% "
35,300	30,000	0.85	0.85	129,100	34,500	40,200	85.9 "	87.0	29.1% "
43,700	38,000	0.85	0.85	135,500	44,700	54,600	82.0 "	85.0	35.5% "

This table refers to a transmission line 127 miles long with 5/0 steel reinforced aluminum, 0.66 in. diameter, spaced 10 ft. vertically on the assumption that the load on the line is at 100,000 volts and 0.85 power factor.

TABLE III

Receiver end of line			Load	Generator end of line				Transmission line	
Kv-a.	Kw.	Power factor	Power factor	Voltage	Kw.	Kv-a.	Power factor	Efficiency	Volts difference
6,600	200	0.03	0.00	112,000	249	1,960	0.12 lead	80.4%	1.7% drop
7,300	6,200	0.85	0.85	112,000	6350	7,710	0.83 "	98.4%	1.7% "
12,000	12,200	0.999	0.85	112,000	12,920	14,200	0.91 "	94.5%	1.7% "
14,400	12,200	0.85	0.85	118,000	12,700	12,700	0.999 "	95.4%	7.3% "
24,000	24,000	0.997	0.85	118,000	25,850	26,000	0.995 "	93.0%	7.3% "
25,900	24,000	0.927	0.85	125,000	25,800	26,400	0.981 lag	93.1%	13.6% "
30 600	30,000	0.982	0.85	125,000	33,300	33,500	0.994 "	90.2%	13.6% "
39,400	38,000	0.965	0.85	133,000	42,700	44,400	0.962 "	89.0%	21.0% "

This table refers to the same line covered by Table II, illustrates the application at the receiver end of the line of two 5,000 kv-a. synchronous condensers controlled by voltage regulators. It is assumed that the load has a constant power factor of 0.85 at 110,000 volts.

With both lines in parallel, a load of 39,400 kw. at 0.85 power factor and 110,000 volts can be carried at an efficiency of 94 per cent, which would require at the generating end 42,000 kw. at unity power factor (42,000 kv-a.) and a voltage of about 118,000. The power factor of the receiver end of the line would be 0.98. The voltage at both ends of the line would be held constant by the voltage regulators in spite of variations in load. With one line, a load of 37,000 kw. at 0.85 power factor and 110,000 volts can be carried at 89 per cent efficiency, which would require at the generating end of the line 42,000 kw. at 0.98 power factor (42,500 kv-a.) and a voltage of 132,000. The power factor at the receiver end of the line would be 0.96. It is assumed that, in the case of transmitting over 18,000 kw. over one line, both synchronous condensers would be available.

As shown in the calculations plotted in Fig. 28, for a range of station load from 0 to 42,000 kw. using one line, automatic voltage regulation could be maintained with voltage difference of 1.7 per cent from no-load to 12,000 kw., of 7.3 per cent from 12,000 kw. to 24,000 kw., and of 13.6 per cent from 24,000 kw. to 30,000 kw. Above 13.6 per cent voltage difference, the synchronous condenser could be operated fully loaded and the generator voltage raised as indicated in the voltage curve. Definite values of voltage difference are given. As may be seen from an inspection of Fig. 28, considerable latitude is available in the setting of this voltage difference. Regulating rheostats can be applied in the circuits of the potential transformers for the voltage regulators, either on the generators or on the synchronous condensers, or on both, and by adjusting them the voltage settings of the regulators can be changed without any adjustments in the regulator itself. In actual operation only such settings should be given, whenever practicable, as bring about the voltage difference that causes the best efficiencies and favorable use of the available kv-a. capacities of the generators and transformers.

Comparing the use of one line to deliver all the power, 42,000 kw., with and without the synchronous condensers, we have the following: voltage regulation at generator end of line 18 per cent against 39 per cent, generator kv-a. 42,500 against 50,600, receiver kv-a. 37,800 against 42,000, and efficiencies 89 per cent against 85 per cent. The voltage regulation without the synchronous condensers is excessive for successful operation; the application of 13,500 kv-a. in synchronous condensers reduces the

kv-a. in the generating station and its transformers by 8000 kv-a. and in the receiver transformers by 4200 kv-a., the price of which offsets the investment for the synchronous condensers; and furthermore, the application of the synchronous condenser due to the improved efficiency increases the output of the line 1400 kw., allowing 400 kw. for losses in the synchronous condensers, a net saving of 1000 kw. is obtained.

Flexible Generator and Receiver Voltages

At a distribution center, it is very desirable to have a flexible voltage, which can be increased as the load comes on, because with power feeders, the voltage drop due to load may thus be compensated for within proper limits, and with lighting feeders, the feeder regulators are enabled to operate within limits of accurate regulation.

A flexible generator and receiver voltage may be accomplished by means of a synchronous condenser and series booster, both machines arranged on the same shaft. The excitation of the synchronous condenser should be controlled with a voltage regulator and that of the booster by hand control. At the generating stations, the excitation should also be controlled by a voltage regulator. At both stations, regulating rheostats should be installed in the circuits of the potential transformers of the voltage regulators. By means of these regulating rheostats, the voltage setting of the busbars can be changed at the will of the operator.

Fig. 29 shows a one-line diagram of a system. In Station C is shown a synchronous condenser and booster for each line. The line constants are assumed the same as those used for calculating curves in Fig. 28. Referring to Fig. 28, it will be seen that, for a given voltage difference and an assumed power factor for the load, the kv-a. of the synchronous condenser will vary definitely with the kilowatt load, and by changing the voltage difference, the kv-a. of the synchronous condenser may be changed: thus, controlling the voltage difference, gives a control of the kv-a. load on the synchronous condenser. An equivalent effect to this can be established by holding the voltage constant in both stations and compensating for voltage by means of a synchronous booster.

The function of the synchronous booster therefore, is to effect voltage compensation, the amount of buck or boost being controlled by the field excitation. When used in connection with

a synchronous condenser, controlled by a voltage regulator, a means of controlling the wattless kv-a. is effected. Without the booster, for a given voltage setting at the generating and receiving stations, the wattless kv-a. supplied by the synchronous condenser will depend upon the kilowatts load for a given assumed power factor. With the booster, whenever the synchronous condenser comes up to its overload limit, the field exci-

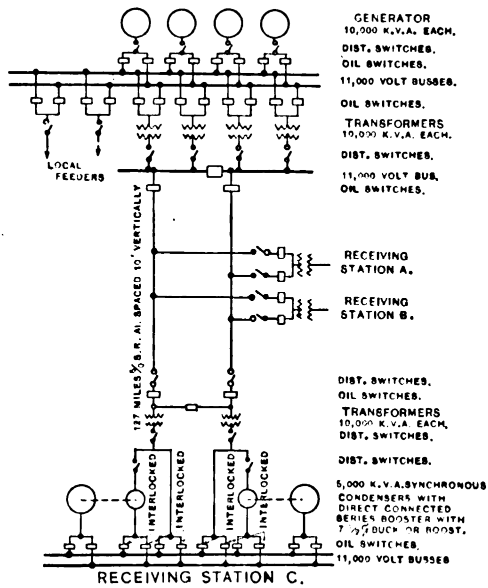


FIG. 29.—ONE-LINE DIAGRAM* OF A SYSTEM TO ILLUSTRATE AN APPLICATION OF A SYNCHRONOUS CONDENSER WITH A DIRECT-CONNECTED SYNCHRONOUS BOOSTER. THE SWITCHES MARKED "INTERLOCKED" ARE SIMPLY TO AFFORD PROVISION FOR CUTTING OUT THE BOOSTER.

* All the disconnecting switches necessary are not shown. For example, each oil switch must be so protected by disconnecting switches that it can be made "dead" to allow repair work. Also provision must be made for testing either line without involving but one generator and transformer.

tation of the booster can be changed to reduce its kv-a. load, without affecting the voltage at either the generating or receiving station, and conversely, when the voltage setting at either station is changed, tending to bring the synchronous condenser kv-a. to an undesirable value, the booster's excitation can be changed, effecting the proper voltage compensation to bring the kv-a. to a suitable value; thus a flexible voltage can be accomplished at both ends of the line, and yet fulfilling the important

requirement that suitable power factor correction may be effected.

In Fig. 29, Receiving Station C illustrates a wiring arrangement for a synchronous booster installation. Not only does the 11,000-volt distribution bus in Station C have a flexible voltage, but so does that at the generating station, and in addition to this, the power factor of the transmission lines is under the control of the operator in Station C. Furthermore this operator is in a position to control the kv-a. of the synchronous condensers so that the power factor in each transmission line is maintained at such values as will secure suitable voltages at Stations A and B, assuming that they are supplied from different lines.

CONCLUSION

1. The necessity of reactance in the circuits of modern systems is well recognized. Its importance has arisen with the growth of large systems, and is essential to prevent destruction by short circuits; to reduce within reasonable limits the size of oil switches, by diminishing the rupturing capacity which they must meet; etc. Transmission lines themselves, due to the spacing of conductors, furnish considerable reactance, but in addition to this, it is customary among operating companies to specify that the generators and transformers be built with considerable inherent reactance. To meet the requirements of some systems, even external reactances are supplied. Now, on the other hand, the development of industrial loads requires the extensive application of induction motors, whose exciting currents cause low power factor. Should these exciting currents be supplied over circuits involving considerable reactance, excessive voltage drops occur. Fortunately, synchronous machines can be located at the distribution centers to supply locally the necessary exciting currents, and by this means maintain uniform voltage regulation. It is not always practicable to locate economically synchronous generators or synchronous motors at the desired points. Hence, the synchronous condenser has been developed. This machine has come to fill an important place in the operation of transmission systems.

2. The combination of synchronous condenser and series booster offers an ideal method of voltage and power factor control. Not only can a flexible voltage be maintained at both ends of a transmission line, but an independent means of power-factor control is secured for the transmission line itself, by which

a definite voltage control is established for some intermediate point in the transmission line. This certainly offers a very considerable advantage, in that it is frequently necessary to have a long transmission line with one or two intermediate stations.

3. A desirable feature of synchronous condensers on a high-voltage transmission system is that they offer protection against those voltage surges that arise due to a sudden loss of load, which might throw the generating stations on the unloaded transmission line with their generators on heavy field excitation. Under such a circumstance, due to the effect on the generators and transmission lines of the leading current set up by the charging current, a destructive voltage would occur. Over-voltage devices may be applied to the generators to give protection; however, with synchronous condensers on the receiving ends of the transmission lines, and each one equipped with an over-voltage device, an ideal solution of the problem is effected, since some of the synchronous condensers could be on the line at all times with their excitation under control through the desired range.

THE DIELECTRIC STRENGTH OF THIN INSULATING MATERIALS

BY

F. M. FARMER

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Abstract of Paper

The object of this paper is to record the results of an investigation which has been made at the Electrical Testing Laboratories to determine the effect of electrode area on the apparent dielectric strength of insulating materials in the form of thin sheets.

The following tests were made with two, similar, flat, circular, electrodes ranging from 1/64 to 6, 10, and 15 in. (0.39 mm. to 15.2, 25.4 and 38 cm.) in diameter and placed directly opposite each other:

1. On insulating cloth and thin sheet hard rubber in air.
2. On insulating cloth in air and in transformer oil.
3. On transformer oil with various spacings.
4. On air with various spacings.

The results of the various tests show very conclusively that the apparent dielectric strength of insulating materials in thin sheet form is materially higher with small electrodes than with large ones. This probably applies generally to all dielectrics, gaseous, liquid and solid, although the amount of variation differs widely with different materials.

The tests emphasize the need for standard specifications for testing insulating materials, especially when in the form of thin sheets. It does not seem probable that the dielectric strength of an insulating material, under all working conditions, can ever be predicted with exactness, but at least we can have standard methods of rating such materials so that a value for the dielectric strength will have the same significance to the manufacturer, the purchaser and the designing engineer.

A paper to be presented at the 289th meeting of the American Institute of Electrical Engineers, New York, December 12, 1913.

THE DIELECTRIC STRENGTH OF THIN INSULATING MATERIALS

BY F. M. FARMER

INTRODUCTION

The object of this paper is to record the results of an investigation which has been made at the Electrical Testing Laboratories to determine the effect of electrode area on the apparent dielectric strength of insulating materials in the form of thin sheets.

It is well known that many conditions affect the results when testing such sheet insulating materials as varnished cambric for dielectric strength. The principal ones are temperature, rate of application of the potential, shape of the electrodes and size of the electrodes. Unfortunately there are, as yet, no standard specifications for testing these materials and each manufacturer, purchaser and testing laboratory uses those methods which seem to be the most satisfactory. In general, varnished cambric and similar materials are tested by placing the sample between, and in contact with, two similar flat circular electrodes to which the potential is applied. The greatest divergence appears to be in the size of the electrodes which vary from needle points to disks 15 in. (38 cm.) in diameter.

The argument advanced in favor of the use of large electrodes is that there is more or less variation in the material, and that the minimum value of the dielectric strength will be found more readily with large electrodes than with small ones. On the other hand, it is contended that the use of very small electrodes introduces an abnormal condition causing concentration of the electrical stress and failure at too low potentials. While much work has been done in investigations of the dielectric

strength of insulating materials, especially air, no data have been published (so far as the writer knows) showing just what effect may be expected with variation in the size of the electrodes, and it is thought, therefore, that the results of some work done in this particular direction will be of interest.

The following tests were made with two, similar, flat, circular electrodes ranging from 1/64 to 6, 10, and 15 in. (0.39 mm. to 15.2, 25.4 and 38 cm.) in diameter and placed directly opposite each other;

1. On insulating cloth and thin sheet hard rubber in air.
2. On insulating cloth in air and in transformer oil.
3. On transformer oil with various spacings.
4. On air with various spacings.

Too many variables enter in tests of this kind to permit a high degree of precision. It is only by taking the average of a relatively large number of readings that even an approximately reliable result can be obtained. However, in these tests, the object was to obtain relative results only, consequently the data should be considered as qualitative rather than quantitative.

Apparatus

Most of the tests were made with a 10-kv-a. transformer connected to a 62.5-cycle, 150-kv-a. generator, but a few of the tests in air were made with two 2-kv-a. transformers. The high-tension voltage was controlled, in all cases, with a variable ratio auto-transformer in the low-tension circuit and measured with a voltmeter connected across the low-tension terminals. Check measurements were made at intervals with an electrostatic voltmeter directly across the high-tension terminals but in no case was any appreciable discrepancy found. Oscillograph records showed that the wave form was practically a sine curve under all conditions prevailing during the tests. The potential was always applied at a very low value (practically zero) and raised gradually and smoothly at a rate of about 1000 to 1200 volts per second. Enough tests (rarely less than ten) were made under each condition to insure an average value of reasonable reliability. The electrodes, which were $\frac{3}{8}$ in. (9.5 mm.) in diameter and over, were flat brass disks 1/16 to 3/16 in. (1.5 to 4.7 mm.) thick with the corners slightly rounded. The electrodes $\frac{1}{4}$ in. in diameter and less, consisted of $\frac{1}{4}$-in. (6.3 mm.) brass rods tapered to the required area at the ends, the corners being slightly rounded.

In all tests on cloth and hard rubber, except those with electrodes over 6 in. (15.2 cm.) in diameter, the electrodes were arranged similar to an ordinary spark gap, being attached to the ends of horizontal rods which were supported by suitable vertical pillars. The specimen was placed between the electrodes which were then brought together with sufficient pressure to insure uniform and complete contact. The pressure was probably never more than a few ounces. Previous tests have

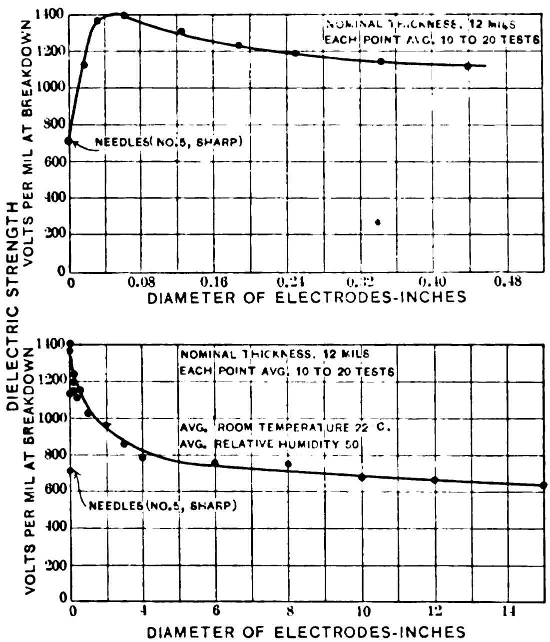

FIG. 1.—EFFECT OF ELECTRODE AREA ON APPARENT DIELECTRIC STRENGTH OF VARNISHED CAMBRIC WHEN TESTED IN AIR.

shown that wide variations in pressures of this order had no appreciable effect.

TESTS ON INSULATING CLOTH AND HARD RUBBER IN AIR

The results of the tests on varnished cambric (nominally 12 mils thick) are given in Table I and Fig. 1. The lower curve shows that the apparent dielectric strength decreases very rapidly from a maximum value as the size of the electrodes is increased, but that the decrease is relatively slow beyond about

5 in. (12.7 cm.) diameter. The total decrease from the maximum of 1390 volts per mil with 1/16-in. (1.5-mm.) electrodes to 625 volts with 15-in. (38-cm.) electrodes is about 55 per cent of which about 42 per cent took place between the 1/16 in. (1.5 mm.) and 4-in. (10.16-cm.) electrodes.

TABLE I.

VARIATION IN DIELECTRIC STRENGTH OF VARNISHED CAMBRIC WITH VARIATION IN ELECTRODE AREA. ALL TESTS IN AIR.

Size of electrodes		No. of punctures	Average thickness, mils.	Volts per mil at puncture		
Diameter inches	Area sq. in.			Max.	Min.	Avg.
Needles	—	12	12.6	960	505	720
0.0156 (1/64)	0.0002	13	12.4	1195	1000	1135
0.0312 (1/32)	0.0008	18	12.7	1430	1260	1370
0.0625 (1/16)	0.0030	15	12.9	1465	1330	1390
0.125 (1/8)	0.0123	15	12.9	1395	1130	1305
0.1875 (3/16)	0.0276	14	12.4	1330	1135	1235
0.25 (1/4)	0.0490	21	13.4	1320	905	1195
0.344 (11/32)	0.0928	10	13.1	1185	1020	1135
0.438 (7/16)	0.150	14	13.1	1225	1000	1115
0.5 (1/2)	0.196	15	13.1	1240	930	1150
1	0.785	15	12.9	1225	910	1030
2	3.14	10	13.4	1030	890	970
3	7.07	10	12.8	1005	665	870
4	12.6	10	11.9	960	615	790
6	28.3	10	12.3	850	690	755
8	50.3	10	12.8	875	685	755
10	78.5	10	12.8	915	550	680
12	113	10	13.0	745	560	665
15	177	10	12.4	685	530	625

NOTE:—Fresh material used in each test.

The upper curve in Fig. 1 is the first part of the lower curve plotted on a larger scale. This shows that a maximum value is obtained with electrodes about 1/16 in. (1.5 mm.) diameter, lower values being obtained with smaller electrodes as well as with larger electrodes. The results with needles (No. 5, Sharp) are about the same as those obtained with the very large electrodes.

Table II and Fig. 2 show the results of similar tests on sheet hard rubber of 7-, 9-, and 12-in. (17.7-, 22.8- and 30.4-cm.) nominal thickness respectively. These tests were not as extensive as those made on the cloth but the curves have the same general shape although the effect of increasing the size of the electrodes is much less marked.

TABLE II.

VARIATION IN DIELECTRIC STRENGTH OF SHEET HARD RUBBER WITH VARIATION IN ELECTRODE AREA. ALL TESTS IN AIR.

Size of electrodes: Diameter inches	Size of electrodes: Area sq. in.	No. of punctures	Average thickness, mils	Volts per mil at puncture: Max.	Volts per mil at puncture: Min.	Volts per mil at puncture: Avg.
		(a) Nominal Thickness, 9 mils.				
Needles	—	11	9.0	1970	1275	1705
0.0156 (1/64)	0.0002	13	8.9	2135	1745	1950
0.0312 (1/32)	0.0008	10	8.8	2095	1710	1970
0.0625 (1/16)	0.0030	13	8.8	2100	1600	1865
0.125 (1/8)	0.0123	15	9.0	2105	1075	1790
0.1875 (3/16)	0.0276	14	8.9	2110	1365	1855
0.25 (1/4)	0.0490	15	8.9	2130	1610	1900
0.344 (11/32)	0.0928	24	8.8	2065	1410	1795
0.5 (1/2)	0.196	16	9.0	1945	1510	1800
1	0.785	9	8.8	2045	1570	1860
2	3.14	11	8.8	1820	1600	1720
3	7.07	10	8.8	1715	1330	1530
4	12.6	8	8.8	1570	1245	1410
6	28.3	10	8.8	1300	885	1180
10	78.5	10	8.8	1875	550	1055
		(b) Nominal Thickness, 7 mils.				
0.0625 (1/16)	0.0030	10	7.3	2000	1730	1865
0.5 (1/2)	0.196	10	7.3	1965	1770	1825
1	0.785	10	7.6	1755	1630	1700
2	3.14	10	7.6	1725	1500	1630
4	12.6	10	7.6	1600	1375	1515
6	28.3	10	7.2	1180	875	1060
		(c) Nominal Thickness, 12 mils.				
0.0625 (1/16)	0.0030	10	12.3	1545	1400	1505
0.5 (1/2)	0.196	10	11.7	1620	1185	1460
1	0.785	10	11.7	1600	1225	1425
2	3.14	10	12.3	1365	1230	1300
4	12.6	10	12.3	1380	1200	1235
6	28.3	10	11.7	1165	955	1015

NOTE:—Fresh material used in each test.

The usual explanation for the lower dielectric strength obtained with the large electrodes is that more "weak spots" are included as the area is increased, thus decreasing the average puncture voltage. This explanation would, at first glance, seem to be entirely reasonable for it is well known that in most insulating cloths the insulating material does not penetrate the threads deeply but merely forms a film on the surface of the cloth and, as the threads vary in thickness, the dielectric strength of the points where the threads cross each other will depend upon the thickness of the threads. Where the threads are thick, the

insulating material will be thin, and vice-versa. Similarly, minute variations in the composition of hard rubber might be expected to make "weak spots" when the material is in very thin sheets. It would seem therefore that the greater the electrode area, the greater will be the variation in the weak spots included, until an area is reached such that the weakest spot is always included. Beyond this point the breakdown voltage would therefore remain substantially constant.

On the other hand, as the electrode area is decreased below

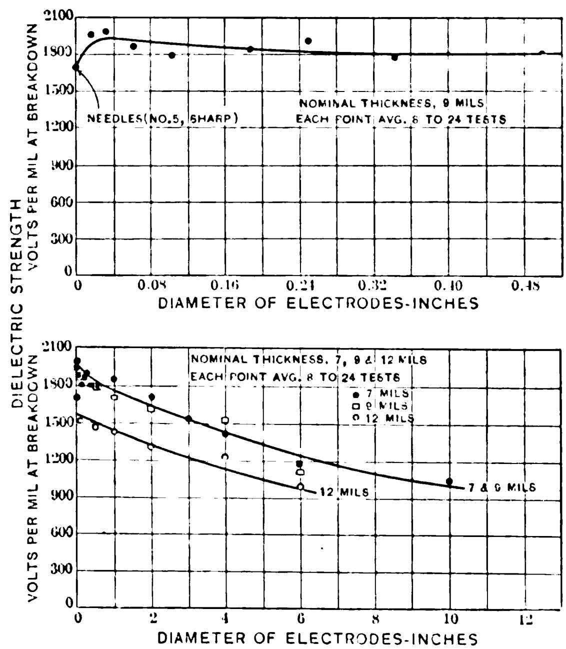

FIG. 2.—EFFECT OF ELECTRODE AREA ON APPARENT DIELECTRIC STRENGTH OF THIN SHEET HARD RUBBER WHEN TESTED IN AIR.

this particular value, one would expect that *occasionally* at least, one of the weakest spots would be included under a given size electrode. An examination of the column of minima in the tables does not show any such result. The figures vary in the same more or less regular manner as do the figures for the average. Furthermore, this explanation does not account for the results obtained with very small electrodes where the most marked effect is found. With such electrodes, it is probable that the air adjacent to the points is broken down long before punc-

ture occurs. This should result in the effective area being increased so that when puncture occurs, this area would be practically the same for all of the very small electrodes. Consequently, according to the weak spot theory, no material variation in the dielectric strength should result with electrodes less than about $\frac{1}{4}$ in. (6.3 mm.) diameter.

It is apparent from the above that the effect of variation in electrode area is not wholly due to variations in the material. With the smaller electrodes at least, it would appear to be due to the change in the distribution of the electrical stress. As the distribution of the stress in the medium surrounding the electrode terminals would be affected by the nature of that medium, some tests were made in moist air and in oil.

Tests on Varnished Cambric in Moist Air

The first tests were made in a box in which the relative humidity could be kept at practically 100 per cent. Considerable difficulty was experienced in getting results which could be duplicated. The following data are fairly representative:

Diameter of electrodes, inches	Volts per mil at breakdown
1/32	1000
1/2	1010
1	1000
3	975

Relative humidity 98 per cent. Temperature 21 deg. cent.

These figures appeared to indicate that with very moist air, the effect found in the first tests does not occur. This is probably due however to the presence of moisture films on the surfaces of the cloth which make the effective area the same for all of the smaller electrodes.

Shortly after the above tests were made, an oportunity occurred to make some tests under practically outdoor conditions on a very foggy day when the relative humidity averaged 90 to 100 per cent. The results of these tests are as follows:

Diameter of electrodes inches	Volts per mil at breakdown
1/32	1170
3/8	1200
1	1200
3	1060
6	950

Relative humidity 90–100 per cent. Temperature 10 deg. cent. (approx.).

These results do not check with those made in the box, although the variation is much less than in Fig. 1, especially with the smaller electrodes. The lack of agreement with the box test may have been due to the fact that the latter tests were made in a draft in an open doorway while the former were made in a box in which the air was perfectly still and where a film of moisture could probably form more readily..

Tests on Varnished Cambric under Oil

The following tests were made on two kinds of insulating cloth with various sizes of electrodes:

(*a*) In air.

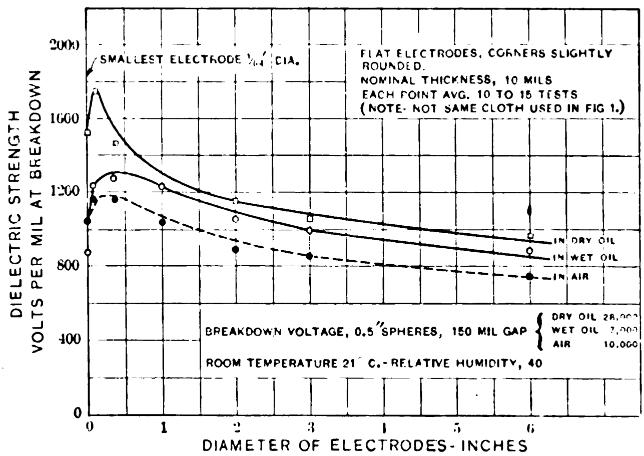

Fig. 3.—Varnished Cambric——Effect of Electrode Area on Apparent Dielectirc Strength in Air and in Oil.

(*b*) Under moisture laden oil having a breakdown value between ½-in. (12.7-mm.) spheres, 150 mils apart, of 7000 volts. This test was made on only one kind of cloth.

(*c*) Under untreated oil having a breakdown value of 28,000 volts in one case and 20,000 volts in the other.

The results of these tests are shown in Figs. 3 and 4. It will be noted that, as found in the previous tests, the dielectric strength increases when the electrode diameter is decreased and that it is uniformly greater when the cloth is surrounded with oil than when surrounded with air. It is also to be noted that with very small electrodes the effect of variation in the diameter is apparently somewhat greater with oil than with air.

Further tests were then made with oil and with air as the dielectric to determine whether they would show the same characteristic curve as the solid dielectrics. Since it was a relatively easy matter to change the thickness of the "dielectric" in these tests, curves were taken with various spacings of the electrodes.

Tests with Oil as the Dielectric

The oil used in these tests was a "water-white" oil, taken directly from the barrel and strained through a double layer of fine silk cloth. It had a puncture value between 0.5-in. (32.7-mm.) spheres spaced 150 mils apart of 35,000 volts.

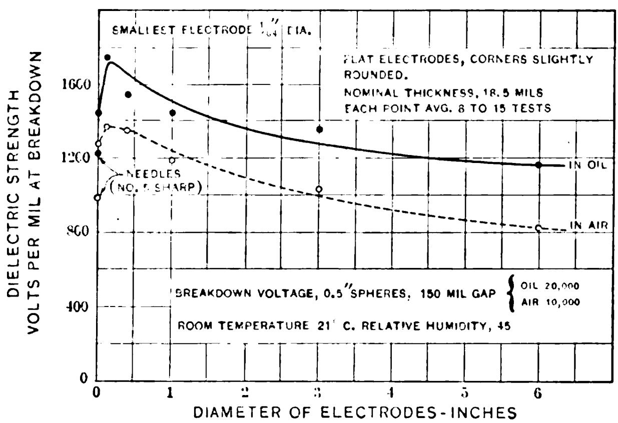

Fig. 4.—Black Varnished Cloth—Effect of Electrode Area on Apparent Dielectric Strength in Air and in Oil.

Tests were made with 1/64-, 3/32-, $\frac{3}{8}$-, 1-, 3-, and 6-in. (0.3-, 2.3-, 9.5-mm. and 2.5-, 7.6-, 15.2-cm.) electrodes and with spacings of 10, 20, 40, 70, 100, 200, 400, and 750 mils.

The results are shown in Fig. 5, from which the following deductions can be made:

(*a*) The dielectric strength increases as the diameter of the electrodes is decreased, *when a thin layer of the dielectric is used*, as strikingly shown by the heavy solid curve which is for 10-mil spacing. This confirms the general result shown in Fig. 1. The effect is, however, much more marked and it is largely confined to the electrodes less than 0.5 in. (12.7 mm.) diameter.

(*b*) The effect of change in electrode diameter decreases as the electrodes are separated, the dielectric strength with the

smaller electrodes becoming smaller and that with the longer electrodes becoming greater. The effect practically disappears at a separation of 400 mils, where the dielectric strength is about 100 to 150 volts per mil irrespective of the size of the electrodes.

(*c*) It is generally known that the dielectric strength of a material is not proportional to the thickness, and that with thin layers especially, the strength increases rapidly as the thickness is decreased. Fig. 5 shows that with 1/64-in. (0.3-mm.) electrodes, the dielectric strength varies from about 90 volts per mil with a spacing or thickness of dielectric of 750 mils to about 900 volts per mil with a spacing of 10 mils. But as the

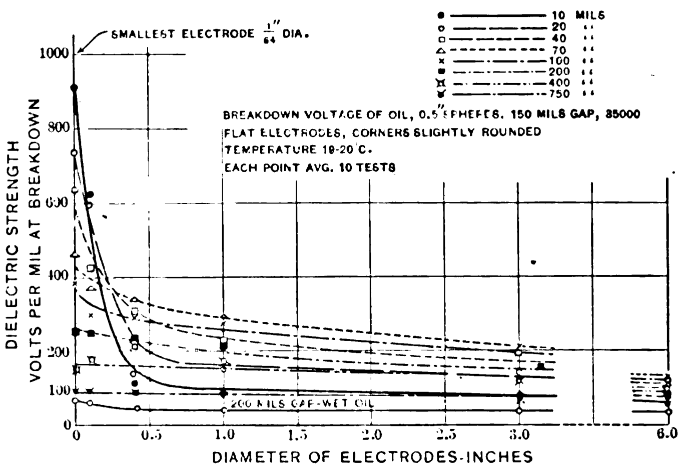

FIG. 5.—EFFECT OF ELECTRODE AREA ON APPARENT DIELECTRIC STRENGTH OF OILS WITH VARIOUS GAPS.

electrode diameters are increased, the dielectric strength becomes more independent of the thickness. At 6 in. (15.2 cm.) diameter, the dielectric strength is practically the same for all thicknesses from 10 mils to 750 mils.

TESTS WITH AIR AS THE DIELECTRIC

These tests were made under ordinary atmospheric conditions and, as only approximate relative data were wanted, no special precautions were taken. The electrodes were simply cleaned by wiping with cloth or filter paper and no attempt was made to have them chemically clean.

The results are indicated in Fig. 6, in which the following will be noted:

(a) As in all previous tests, the electrode area has a marked influence *when the dielectric is thin*.

(b) The dielectric strength is higher for thin layers than for thick ones, a characteristic which has been found by many experimenters. Unlike oil, however, the dielectric strength varies inversely with the separation for all sizes of electrodes, but the variation is much greater for the small electrodes.

(c) There appears to be a certain thickness of air (about

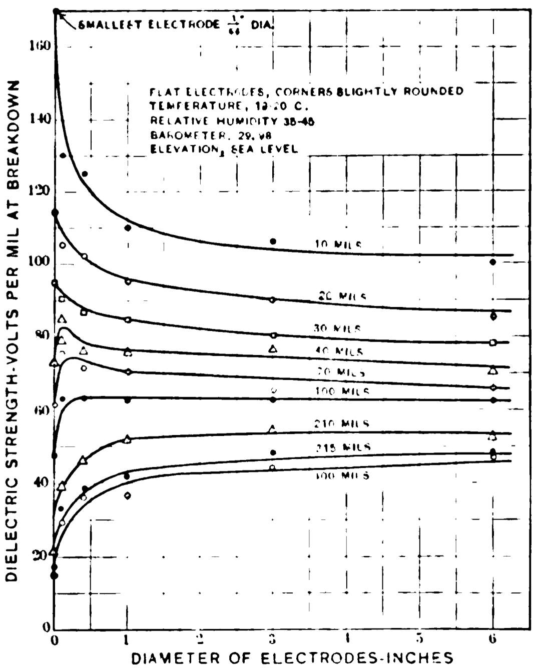

Fig. 6.—Effect of Electrode Area on Apparent Dielectric Strength of Air With Various Gaps.

100 mils) where the electrode diameter has no effect. With smaller separations, the dielectric strength increases as the electrodes become smaller, and with greater separations the dielectric strength decreases.

Additional Tests with Solid Dielectric

The results of the tests in oil and air having indicated that, in those cases, the effect of variation in electrode diameter

occurs only with very thin layers, a few additional tests were made on hard rubber of various thicknesses. These tests were made in oil.

Not enough time or material was available to make these

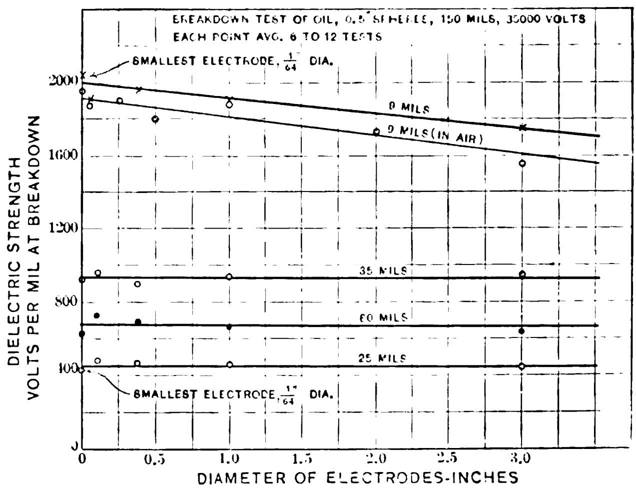

FIG. 7.—HARD RUBBER IN OIL—EFFECT OF ELECTRODE AREAS WITH VARIOUS THICKNESSES.

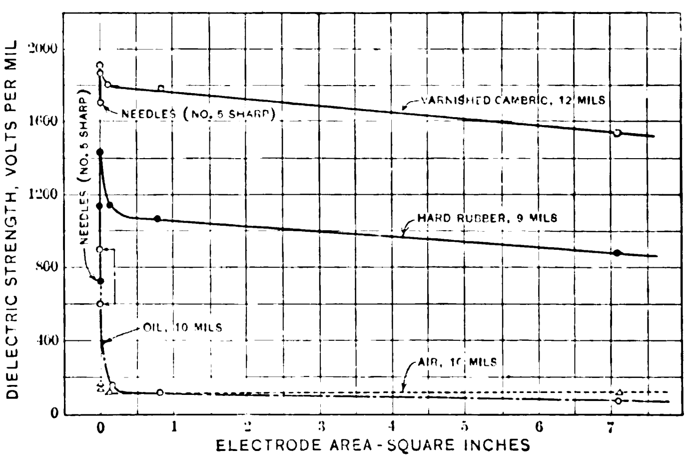

FIG. 8—DIELECTRIC STRENGTH VS. ELECTRODE AREA IN SQUARE INCHES

tests as complete as would be desirable, but the results, as shown in Fig. 7, appear to confirm, in a less marked degree, those found for oil and air. That is, this variation with electrode area is found only with thin dielectrics.

Conclusions

In work of this kind, so many variables enter that a high degree of reliability can not be expected. Although the results given are averages of a great many determinations, it is felt that considerable allowance must be made in drawing final conclusions. Furthermore, a great deal more work is necessary, such as an investigation of other classes of insulators, effect with electrodes of various forms, effect of other surrounding media including solids, et cetera. However, so far as the original purpose of these tests is concerned, viz., the effect of the variation of the electrode area on the apparent dielectric strength of thin insulations, the following conclusions may be drawn from the results:

1. The apparent dielectric strength of insulating materials in *thin* sheet form is materially higher with small electrodes than with large ones. This probably applies generally to all dielectrics, gaseous, liquid and solid, although the amount of the variation differs widely with different materials. The variation with ordinary sheet insulating materials, such as paper and cloth, may be 40 or 50 per cent. between 1/64 in. and 8 or 10 in. (0.3 mm. and 20.3 or 25.4 cm.) diameter while with oil, under the same conditions, the variation is over one thousand per cent.

The prevalent opinion is that the electrostatic stress is concentrated when the dielectric is between sharp points and that failure will occur at a low value. This appears to be the case when the points are very sharp, such as needle points, but as soon as they have an appreciable area, the puncture value is much higher than with large electrodes.

2. These tests emphasize a need which has been frequently pointed out in the Proceedings of the Institute, viz., standard specifications for the testing of insulating materials, especially when in the form of thin sheets. It does not seem probable that the dielectric strength of an insulating material under all working conditions can ever be predicted with exactness, but at least we can have standard methods of rating such materials so that a value for the dielectric strength will have the same significance to the manufacturer, the purchaser and the designing engineer.

Discussion on "Purchased Power in Coal Mines" (Eddy) and "Central Station Power for Coal Mines" (Beers), Pittsburgh, Pa., April 18, 1913. (See Proceedings for April, 1913).

(Subject to final revision for the Transactions.)

K. A. Pauly: We are very fortunate to have secured these valuable papers on this very important subject of central station versus isolated plants for coal mines. Many of the points brought out might readily form the subjects for separate papers. Such papers are especially valuable because they give the views of engineers, who, because of their experience, are eminently competent to deal with the subject. I do wish, however, to point out and emphasize the agreement between these three engineers whose opinions are based on actual and independent experiences, representing both sides of the question. While there are doubtless large mining companies which can and do maintain highly efficient and economical electric generating and distributing systems, it appears to me to be a foregone conclusion that in general—and this is especially true of all but the larger companies—a public service corporation should be in a position to deliver power at a lower cost than it can be produced in an isolated plant and that, in addition, the service should be much more reliable.

We have, on the one hand, a mining company whose efforts are devoted to the production of coal at a minimum cost, and in which cost the item of power plays but a minor part. In addition to this the power cost is handicapped by a low load factor, resulting in high fixed charges and operating costs, which combine to give a high power cost. On the other hand, the one object of the public service corporation is that of developing cheap and reliable power. It maintains a competent corps of engineers who devote their entire time to the problems incident to the development of cheap and reliable service. They have at their command the necessary capital to introduce improvements and make extensions, which make for lower power cost. Assisting them in their efforts, they have the greatest diversity of loads to bring up their load factor. To sum it up, so to speak, the one is a coal manufacturer and the other a manufacturer of power.

There is but one detail to which I wish to refer in connection with these papers, and that is the question of steam and fuel consumption brought out in Mr. Beers' paper. The contention made by the advocates of the isolated plant, as has been pointed out, is that the price of coal is low. Fuel is but one of the items entering into the cost of power, and the low priced fuel is not necessarily the most economical to use. These inferior grades are high in ash content, require more labor in the boiler plant, and cause a considerably higher cost for maintaining the boilers which may nearly, if not quite, offset the low cost per ton for fuel. I am especially interested in Mr. Beers' statements with regard to the steam and coal consumption of the present, in

many cases, obsolete steam equipments about the mines. We advocates of the application of electricity to mining operations have always contended that the actual steam consumptions are far in excess of the figures given by our steam competitors, but never before have we had so complete and positive a statement of the facts as is given in Mr. Beers' paper. Much of this inefficiency is due to wear with age. Contrast with this the almost constant efficiency with the electric motor, which varies but slightly with length of time in service. Again, a great deal of the high fuel consumption is chargeable directly to the low load factor, under which the small isolated plants are operating. I am familiar with a seven day test of a large mine hoist which gave approximately seventy-five pounds of steam per shaft horse-power-hour as the water rate of the engine, and showed that the fuel consumed during the idle period of the hoist was approximately 50 per cent of that required for hoisting.

George H. Morse: Mr. Eddy has remarked that the power plant of the mine is by natural causes necessarily located at the least advantageous point, that is, at the mouth of the mine.

Those are natural causes of disadvantage. I recently installed a fan plant in Eastern Ohio, which suffered from difficulties which came through artificial causes. I refer to the recent law passed in Ohio limiting the voltage to 250 volts in the mines. Two hundred and fifty volts may do for some mines, but there are other mines, which are of sufficient length to make it necessary to use 500 volts, if power is to be transmitted from the mouth of the mine to the interior of the mine. I have in mind one mine at Wheeling in which they have for several years used 220 volts. The mine has gone on increasing in length, and the next step was to introduce a booster, because the voltage was low and the motors heated, and now the booster is not sufficient, and at the mouth of the mine, there are perhaps a dozen large cables, of 600,000 cir. mils waiting to reinforce the copper. These conditions notwithstanding, the point I wish to emphasize is this, that the position taken by the legislature in Ohio, in permitting even 250 volts to be used in mines, is, in my opinion, wrong. Two hundred and fifty volts is, to the speaker's thinking, too high. In fact, if we could have the power introduced into suitable points in the mine at high and workable voltage, so far as primary is concerned, and then reduce it even to as low as 50 volts, I think that insulation troubles and death from electric causes would be very much reduced.

E. D. Dreyfus: The various papers that exemplify the advantages of "importing" power to the coal mine add another chapter to "exploded" theories. On first thought one would naturally suppose that coal as it was disemboweled from the earth could be most economically converted into power on the spot for use on the premises. But this now has been generally proven to fall far short of reality owing to the modifying and

militating conditions which have been discussed. The ideas held by our forebears likewise conflict with the present developments, as is evident in referring to the saying originated by an English writer by the name of Fuller, in 1661, "To carry coals to New Castle" (the Pittsburgh coal district of Great Britain), which was used as an expression of a preposterous situation. This conception is no longer valid since we see on every hand power companies delivering the energy equivalent of the coal to the very heart of the mine at distances that already greatly exceed 50 miles. The evolution curiously does not stop at this point, for we are beginning to witness a gradual substitution of the "black diamond" for producing the power required in coal mining by a much more valuable resource in the nature of "white coal" or water power.

The march of progress in this direction has been very marked. In rather limited time, I have personally observed over 200 coal mining companies that have become users of central station power, and this I know is a small percentage of the whole, and the rapidity with which new mines are added to the lists seems to be mostly a factor of time in which the power companies find themselves able to extend their service to the scattered locations. The coal mine operator through his lengthy experience in the production and utilization of coal intuitively becomes a very capable judge of the unit value of power, which often makes "fine haired" figuring unnecessary with him. If ideal cost only were considered the increased use of purchased power by the coal mines would have been impeded, but the practical sense of the operator has fortunately prevailed. I mention these facts merely to indicate that we must go cautiously into the subject of general cost of power. To do it justice we will have to cover an almost limitless field. There are more variable factors and intangibles in power costs than many of us are able to appreciate, and to broadly compare rates, prices or cost without a definite accounting of conditions would be entirely improper. In the philosophy of power costs there must be a liberal reckoning with the various elements that go to make up the total expense. And by virtue of these conditions no two installations or situations in any two districts are directly comparable.

The Pittsburgh district has evidently been the pioneer in this country in applying central station power to the coal mine on a large and extensive scale, and other territories have been able undoubtedly to profit by the important development wrought in this region. But the economy of production has in the meantime advanced to such a degree that the tonnage costs under similar circumstances would be lower than in other localities even if they were to pay higher prices in some cases. However, on examination, and with load factor and surroundings balanced, it is believed that it will be found that the Pittsburgh district enjoys very excellent rates which correspondingly are at the

lowest possible level when favorable operations either obtain or are assumed.

Finally we should regard the character of the mine electrical equipment as carefully as the cost and reliability of the central station supply. I can not urge too strongly the employment of the best talent in planning and executing the local installation. Central stations invariably prefer to serve mines in which the application of electrical equipment is properly made, rather than where the apparatus and methods are inefficient, although the amount of power consumed is greater in the latter case. They desire that the service be entirely satisfactory in every respect even if it results in a smaller income to them. Some of the good work that has been carried out under the supervision of our professional electrical engineers has been prominently reflected in the success and economy of the mines for which they have stood responsible.

T. E. Tynes: As to the points enumerated in Mr. Beers' paper, I fail to see any mention made as to whether the coal operator is reimbursed for interruptions to his service, incurred by the power company.

W. Partridge: I would like to call attention to Mr. Beers' figures in which he apparently shows that power can be produced for 8 mills. This may be true in Mr. Beers' case, with a comparatively large station of about 1000 kv-a., and with 85 and 50 per cent load factors, but in the mine plants with which we have had experience the load factor is nearer 20 per cent. Also most of the mining operators are willing to charge for their coal the price which they can get for it on the cars, which would be, at least $1. If you do a little figuring, changing the load factor, and changing the coal, you will, in small plants of 100, 200 or 300 h.p., get a cost in the neighborhood of 2 cents per kw-hr. Recently in Boston I ran across an engineer accustomed to install small plants in mills and factories. His ideas and mine on the subject of power costs were entirely different. He started out by saying that he thought it was absurd to think that at a coal mine, power could be bought from the central station cheaper than it could be manufactured, and then he asked what our rates were. I told him in the case under consideration the rate would be somewhere around 1.5 cents per kw-hr. He thought that that was too low, and that any company that was willing to make a contract to supply power for 1.5 c. per kw-hr., should be required to give a bond to the company with which the contract was made, for fear that the power company might wind up at any minute. Then afterward he got out his pencil and started to figure what he could make the power for, and before he got through he had it down to $\frac{3}{4}$ ct. per kw-hr., including the fixed charges for a little plant of about 200 h.p. He did not like to figure on a kw-hr. basis. His figures were on the h.p. basis, and one of his claims was that he could and was producing power in a number of plants in New

England on 1.5 lb. of coal per h.p-hr. I afterwards came to the conclusion that one of the ways in which he was fooling himself and his customers, was this. He would take an engine installation, of say, 300 h.p., and take the total cost of operating the engine for 10 hours a day throughout the month, and then assume that the engine was carrying full load during the entire period. Such a basis is easily exploded by taking indicator diagrams on the engine, and those who are familar with selling power on a kw-hr. basis know that the load factor on almost any type of machinery is generally nearer 20, 30 or 40 per cent than it is 100 per cent.

W. E. Dickinson: Practically everything has been said on the side of central stations that can be said, and I have nothing to add, but for the sake of argument I want to call attention to a few points that may suggest a debate here. I should like some one to take sides against the central station to open a debate, knowing the popularity of the central station in connection with coal mining operations.

Mr. Beers in his paper brought out the fact that much steam was used around the coal mine anyway. So, I ask, has he charged up in the fixed charges the expenses of that part of the steam plant used purely and distinctly and entirely for the electrical side of his power plant, or has he charged in repairs and depreciation, etc., for that part of the boiler equipment that is to be used generally for other purposes?

He has brought out the fact that power generated today at 8 mills has been satisfactory. I should like to know what central station company will sell power at 8 mills. I should be glad if any one here, who is willing to make a contract to sell power at 8 mills, for a fairly long period, will let me know where I can see him to arrange for the purchase of power on that basis, as I should like to jot it down for future reference. If you begin to bargain with a central station power plant for power, they are more apt to charge about 2 cents or 3 cents, than 8 mills or 8.5 mills. To purchase power at 8 mills is certainly unusual.

Mr. Beers spoke of it being only fair to pay 15 per cent on the first cost of the pole line. Has he added that into the cost of his power?

Then, his definition of the substation is rather a complex one. He speaks of the substation as being at any prearranged point in one colliery, for instance, at the entrance thereto; while Mr. Eddy speaks of the advantages of the central station because of the ability to move the motor-generator set from one point to another, and the probability of being able to duplicate motor-generator sets and of placing them at several points. I ask whether the attendants upon the motor-generator set or the synchronous converter would not make an additional cost to the coal company? Neither speaker seems to have considered this expense.

Now, another point that has been suggested as favoring the use of central station power is changing the feeding point. Would not that also be possible in using a local power plant, and would not that also entail additional cost?

The making of a long term contract may be beneficial to the coal company, but it may be detrimental to the coal company, under certain conditions, because of the fact that the long term contract is binding upon either company. If, in any way, the coal company should find it to its advantage to make some change in its equipment, it is bound down by a long term contract. The time may come when the erection of its own central station may be justified by the extension of its property.

I believe that those are about the only points I noticed especially that might be brought up for argument.

H. C. Eddy: Various companies that are incorporated under the title "American Gas & Electric Company" are entirely willing to sell power under certain conditions at 8 mills, or even slightly under 8 mills. The cost of producing that power is easily all of that, or perhaps more, and it might be a pertinent question to ask how we can make money by selling power at less than it costs to produce. The answer to that is very simple, it is composed of two words: Diversity factor.

You have an output in a certain given plant of a certain number of kw-hr. per month or per year, which costs to produce at the switchboard a certain amount, suppose we say it costs 8 mills to produce it. That, under ordinary conditions of load, means a comparatively low plant load factor for twenty-four hours, and it is the twenty-four hours' expense that is the most important. The result is that if we can find a customer who will use our facilities and our capacity and our investment, during those hours in the twenty-four when the majority of our customers do not use these things, we can afford very well to sell that power during those hours at about the cost of production, and make a profit, because it will reduce our total cost per kw-hr. for all that we turn out.

There was one other point that the gentleman brought out, and that was the matter of the change of location of motor-generator sets. He suggested that that might be equally feasible in the case of an individual mine power plant. It is, provided the individual mine power plant has the necessary equipment to transmit current for considerable distances with slight loss; in other words if the plant is equipped with alternating-current generators and can deliver current at anywhere from 2300 volts upwards, they can install motor-generator sets, with synchronous converters, and move them about with the same facility as though they were purchasing power, but the fact remains that there are only one or two coal mining companies that do busines on that basis. They are very large, and they have that sort of equipment. The average coal mine, however, has one or two 150-kw. generators, 220 or 500 volts. Occasionally you will find a mine that

has a generator of 300 kw. capacity in one size, or something of that kind, but in this section of the country, with the bituminous mines, at least, they run to small units as a rule.

The result is that if they were to sacrifice the present equipment and replace it with the proper amount of alternating-current apparatus, and then were to go further and buy the necessary conversion equipment, their plant cost would continue to go up, and their fixed charges would be correspondingly higher, and their cost per kw. hr. would be increased, so that, even under those circumstances, it would be cheaper for them to limit their investment to the conversion apparatus only, and then place it where it will do the most good.

George R. Wood: I think Mr. Eddy underrates the average size and number of central station mining plants. There are today between 15 and 20 a-c. mining plants with substations, and I believe the average d-c. plant is 300 kw. or over.

There is one additional advantage in purchased power, compared with your own d-c. plant. In the latter case, as the mine advances and requirements increase, an addition to generating capacity means an investment of $80 to $100 per kw. With purchased power, only an additional substation is required, with investment of $15 to $20 per kw.

C. W. Beers: In regard to the power company paying the coal company for delays, I want to say that there is a penalty clause in our contract with the power company from which we purchase power, and under which they are responsible for delays.

They agree to pay our company a certain sum of money, to be reached by agreement, for any delays that occur which are serious enough to interrupt the operations of the mining company. We also have in that contract a clause which gives the power company the right to ask us for delays or interruptions, without charge. For instance, they may want to do something to their generator plant, and we could afford to shut down, say, from some period on Sunday until some later period on Sunday evening, or from Saturday evening until Sunday morning, or something of that kind, so that we are advised in advance to make these arrangements; but for unexpected delays in our operations, resulting from the power company failing to give us power, and which result in damage to us, the power company will pay us a certain sum of money.

In regard to the question of bringing up the case of cost of steam in electrically operated plants, we have no steam at those collieries that we propose to operate electrically. We may bring up the question of heating at these particular plants, but we have not got up to the point yet where we are really running any boiler plant for heating purposes at all. So far we have confined ourselves to a small test, that we are now conducting, in regard to heating by stoves or heating by electric power. We have not come to any particular conclusion on that point, but at one big colliery, that we are proposing to operate entirely

by electricity, we will probably during the cold winter months run a small boiler plant.

With reference to the question as to what power company sells power for 8 mills, in the case of the power company I am buying from, we are paying monthly bills now as low as 5.3 mills per kw.

In regard to the question of pole line cost, whether or not we have included this in our annual costs, I want to say we have not included any pole line costs so far, because as soon as we get a line in we propose to load that line up. We want to keep above the minimum charge. We think that is our privilege to do. Where we do not use power, we pay the 15 per cent, but we do not propose to have a line go in and not use it. We expect to use every line and to load it up.

Discussion on "Safeguarding the Use of Electricity in Mines" (Clark), Pittsburg, Pa., April 18, 1913. (See Proceedings for April, 1913).

(Subject to final revision for the Transactions.)

C. A. Lauffer: During the past four years I have been an advocate of the Schafer prone pressure method. This method bids fair to become the universal method employed for resuscitation. During this time it has been my privilege to instruct over two thousand men in giving artificial respiration, and I have done considerable writing and speaking on the subject of artificial respiration.

But in coming before you today, I came expecting to hear what somebody else was going to say. It did not occur to me that your chairman would call upon me. I presume that every gentleman here has read the report of the National Electric Light Association on the subject of resuscitation. The Committee appointed by that Association, which was composed jointly of prominent engineers, and eminent physicians agreed unanimously that the Schafer method is the most promising method to employ in efforts at resuscitation. When the manufacturers of mechanical devices produce something that every electrical workman can carry round in his vest pocket, then we will agree that the manual method can be supplanted by the mechanical method, but so long as mechanical devices are so large and so difficult to have when they are most needed, if we neglect instruction by manual methods, the present loss of life will continue to be disastrous.

As to the mechanics of artificial respiration by the prone pressure method, we know that in breathing, the main muscle which is used is the diaphragm. The diaphragm is arched, and above the diaphragm lie the lungs and the heart. Below the diaphragm, under these ribs, up to the fifth rib lies the stomach. On the other side lies the liver. Below these organs, behind, lie the two kidneys. Behind the stomach on the left side lies the spleen.

Now, when we give artificial respiration by the prone pressure method, we lay a man on his stomach and turn his head to the side. In turning his head to the side we prevent the mouth making contact with dirt or water. We turn his head to the side, and that permits any fluid in the mouth or air passages to run out. When we lay him on his stomach and turn his head to the side his tongue falls forward. There is no necessity of any device to pull the tongue forward, because gravity causes the tongue to fall forward. With the patient in that position, lying prone, with his arms spread out, or above his head, we proceed to make pressure on the lowest ribs. The pressure is made on the eleventh and twelfth ribs with the heel of the operator's hands, and the pressure is made far out towards the ends of the ribs. When pressure is made that way for three seconds, it is possible to empty the lungs, it is possible to drive out more air than is ordinarily driven out in our natural breathing, so that by making the pressure

twelve times a minute, and completely removing our hands after each pressure, we see at once that we are giving the man more cubic inches of air than he gets in his natural breathing, and we are bringing back into play the diaphragm; we are forcing these movable organs of the abdomen up against the diaphragm in a manner that not only restores the action of the lungs but also assists in maintaining the action of the heart. We cannot give massage of the heart, such as is done sometimes during abdominal operations, manually, but we can give massage of the heart by throwing these movable organs up against the diaphragm twelve times each minute. There have been several instances where victims of electric shock, declared dead by physicians, were brought to by friends of the apparent victims. It very often happens that linemen and electric workmen have better muscles than doctors and more courage and consequently more success; because, with the people who have the courage, the tenacity of purpose, this prone pressure method succeeds admirably in quite a number of cases.

J. S. Jenks: I will ask the doctor a few questions for the benefit of some of us here concerning the length of time it would be advisable to keep up such action, and the advisability of the use of stimulants, and methods of administering them, and methods of aiding and assisting the heart and lung action by hypodermics or some such thing as gases of different kinds, or the reëstablishing of breathing by slight electric shock.

I have given this matter considerable thought, and have tried to instruct and train our men in the manner in which they would be able to take care of their comrades in case of accident, and have supplied them with small cases containing hypodermics, atropin, nitro-glycerin, strychnin, etc., and gave instructions where they could procure such gases as would be advisable and advantageous in producing results in extreme cases.

Now, the thing that has impressed me—I have been at a number of cases of accidental shock—is the fact that everybody gets excited, that they go to work with a vim, and work at high speed, and do not take the time that is necessary. I want to emphasize that point of the time element. I have tried to tell our boys and instruct them to count three slowly after each operation, and if they do not do that, they get all worked up, and do not see results, and tire themselves out readily, and give up, and I believe many a good man dies just on account of a man's over-exertion in the early part of the attempt at resuscitation.

I would like Dr. Lauffer to elaborate on the time a man should continue to work. I have known of several cases where there was complete resuscitation after periods of one and three-quarter hours of continuous and unceasing efforts by fellow workmen and physicians and attendants. I have also known of cases where we had very extreme cases of burning and apparent death, and the victim was brought around in as short a time as three minutes through the aid of some stimulation.

C. A. Lauffer: The best gas to inhale is aromatic spirits of ammonia. That is readily available. If you do not have aromatic spirits of ammonia, use any kind of ammonia. If you use aromatic spirits of ammonia, the handkerchief can be saturated and held about three inches from the nose. If you use household ammonia, and it is full strength, try it on your own nose first—dilute it with water, or hold it farther away—and do not take an unfair advantage of an unconscious man. Then as to oxygen, I think aromatic spirits of ammonia is superior, provided you are in the fresh air. In the case of mine gases and various chemical combinations, it seems to me that oxygen, under certain circumstances, is superior to fresh air and ammonia.

No liquid should be poured into the mouth of an unconscious man.

Now, as to hypodermic medication, we never instruct the men to give that themselves. There is usually a doctor available, and the hypodermic drugs have to be administered with much care. The best drug is atropin, the second best drug is strychnin, and when you are not getting results, you give both; both right away, and as soon afterwards as you can, it is a good plan to give digitalin, cactin and camphor in oil, and then other hypodermic stimulants, such as the physician may have with him.

As to the amount of stimulation which you can give, that is a question which ought to be left with the physician. To a certain extent you can whip a mule and make it go, but after a while the mule will drop dead, and it is the same way in the matter of stimulating the heart. To a certain extent you want to stimulate but beyond that too many doses of strychnin are going to prove fatal.

I took no notes of your questions, and consequently I may miss some of them. There was a question asked as to the duration of the treatment. I have known results to be delayed for two or three hours, and in some cases I have seen results come within less than twenty minutes. I know of one case in particular where everybody thought that the man was dead. He was a man about fifty-seven years of age; he had fallen nine feet, lighting on the concrete floor, with his whole weight, on the back of his head, and he was a heavy man. He had a marked case of concussion, and was unconscious; he had no respiration or pulse, and with the stethoscope you could not hear his heart. His comrades knew about artificial respiration and kept busy, and my assistant reached the man and worked over him, giving him artificial respiration; and then he started to breathe and soon stopped again, and as soon as he would stop they would start again, and by keeping him on his stomach and giving artificial respiration by this method, in about one hour's time he came to sufficiently to vomit, and from that time was able to breathe normally. Under ordinary circumstances a man who sustains a fall on his head, or a man who gets a blow in his solar plexus, is going to die, because there is no one around who knows how

to give artificial respiration; the general public must take up the subject of artificial respiration and learn how to give it, for you cannot expect doctors endeavoring to reach the scene, always to arrive in time. These people must be assisted. If a man has not breathed in two minutes, he is in as great danger as a man who has been without food for forty days.

Ralph D. Mershon: I noted the pressure you exerted was long-continued and slow, and I judge that is an important feature of the treatment.

C. A. Lauffer: That is the best way, begin the pressure gradually, and continue it until you feel the ribs give way under your hand. Some people are much firmer in their ribs and in their costal cartilages than others; and occasionally you run across a conscious man in these exercises who will exert all the force he has to prevent your giving him the artificial respiration, but when the patient allows himself to be perfectly passive, you will find that a few pounds of pressure will be ample. You can apply the pressure gently, gradually increasing, and when you have reached the limit of compression, then suddenly remove your hands. As you remove your hands, those organs which you have displaced upward by the pressure will drop down again; the diaphragm will descend and the air will rush in. As you make the pressure you raise the diaphragm and compress the lungs and drive out the air. As soon as you remove your hands, these organs fall back into their former places.

The question has been asked if there is any danger of breaking the ribs. I think not. I have never heard of it happening. I suppose if you put enough weight on you can do it, but the blows which break ribs are sudden blows. A man does not break ribs from lifting, and he does not have his ribs broken from such a gradual, firm pressure on his ribs. The only person who can experience any damage by the prone pressure method of treatment is somebody with cancer of the stomach or liver, or a far-advanced case of tuberculosis, but the people who are a living pathological museum are not the men who are engaged in the active pursuits of life.

George R. Wood: I would emphasize that for the purpose of the mining men, we can almost disregard the matter of hypodermics and the other administration of medicine. What the mining man should do is to send for a doctor and then start artificial respiration, and let the company doctor do the other things.

Graham Bright: Mr. Clark brings up the question of sand on the track insulating the locomotive and causing current to go back through the cars and create trouble. This is a point which has caused a great deal of contention between the manufacturers and the operators in that the operator sometimes wants a locomotive that is too light. The result of a light locomotive is that he has to pile sand on the track to get the cars up the grade, causing a great deal of dusty grit to work its way into the

bearings. It would be very much to the advantage of the operator if he would either obtain a locomotive large enough, or cut the trips down, so that he does not need the abundant use of sand. Aside from this damage, and the damage or trouble mentioned by Mr. Clark, another trouble exists, in that you provide a sand path for the cars to run on, which, of course, increases the rolling friction of the locomotive and cars, and you also cut down the available voltage for the locomotive by increasing the electrical resistance between the wheels and track. As brought out in Mr. Eddy's paper, low voltage is the cause of a great many of the troubles that take place in mine locomotives and is the cause of much of the high upkeep, owing to the windings of the motors burning out.

Another point Mr. Clark has brought out is the question of storage battery locomotives for mine service. Any one who has had very much to do with storage batteries knows that they require rather expert attendance, and we can well imagine what will happen to the average storage battery that does not receive any more attention than the average mine locomotive gets. In the first place, many of you who have been in mines have no doubt noticed that a considerable number of the locomotives will have their side or end frames cracked or broken, showing that in mines as well as railways on the surface, we have not yet solved the problem of two locomotives running in opposite directions on the same track. You can imagine what would happen to the ordinary storage battery in one of these collisions, so that if we are going to go to storage batteries, we must select one which is mechanically strong and will stand these collisions which are liable to occur in the best regulated mine.

Another point about these storage battery locomotives is that there is a tendency among some of the smaller manufacturers to build a locomotive which they can offer for a very low price. The locomotive must necessarily be of light construction, which makes it totally inadequate to meet the severe conditions about a mine. If we are going to build a storage battery locomotive it must be amply strong to stand the rough usage incident to the mine service, and a locomotive to withstand that service cannot be obtained in the case of many of the storage battery locomotives in industrial service at present. Industrial service is generally outside in the open, or in well-lighted buildings, and the chance of collision is very small. They can get a better class of operators, because industrial plants are, as a rule, located in large industrial centers where the living is much better and it is a comparatively easy matter to get a good class of men to take care of these locomotives, so while the storage battery locomotive sounds like a good way out of some of our difficulties, in the way of protection from electrical trouble, there are a good many details to be worked out, before it can be made a successful gathering locomotive.

W. E. Dickinson: There is one subject that Mr. Clark treated in his paper that is of special interest to me, viz., the accidental

discharge of shots after the charge has been made. As most of you know, this matter was investigated to a certain extent in Kentucky, and it was thought to have been demonstrated that stray currents have fired shots when copper needles were used. I believe that it was stated that within a mine investigated, considerable electrical potential existed between certain points, sufficient, it was decided, to produce in the explosive a current large enough to ignite the shot.

I do not understand how such a conclusion could have been drawn. It is an easy matter to find with a sensative voltmeter a potential difference between two points in a mine. But it is difficult to get an appreciable current to flow through even an ammeter connected to these two points, owing to the internal resistance of the circuit through which the current must flow. Moreover, the explosives used in shot firing are of very high electrical resistance. Admitting that the current may travel through the copper needle, it must then find its way through the explosive and be large enough to generate therein sufficient heat to fire the shot. It is quite doubtful that even stray currents leaking from trolley to track would select the high resistance path of the explosive material. But it is very probable that leakage currents will enter poorly insulated detonator leads under favorable conditions and thus prematurely discharge a shot.

Mr. Clark said, however, that if currents are held within their proper channels by proper insulation, it is not possible for them to ignite shots. I can not entirely agree with him on this point. I believe that many accidents in mines are due to induced currents in short circuits, regardless of the nature of the insulation of the power lines.

Some time ago my attention was called to an accident which occurred in West Virginia, in which a shot was fired prematurely when a hand generator was to be used. The leads from the detonator had been untwisted and brought out separately into an adjacent passage. The generator was then placed between the rails of the motor track and connected to the detonator leads. When all preparations had been made as usual, the operator attempted to fire, the shot failed; another attempt to discharge the generator was made without success. The man was about to investigate the trouble when the shot went off unexpectedly. Fortunately, he was not seriously injured, and lived to describe the conditions.

There was a motor operating on the track, and you know that a motor in starting up will draw an immense current for a short time. This current sets up a rapidly changing magnetic field around the track and trolley. And such a field of flux, when favorably cutting a closed conductor of low resistance, may induce in a circuit a voltage sufficient to produce a current large enough to fire a shot. So, it occurred to me that a premature discharge of a detonator might be attributed to induced currents under favorable conditions. I do not know that this was the

specific cause in the case described, but I could not attribute the accident to leakage currents occasioned by poor insulation. I feel sure, however, that under certain conditions it is possible for such an accident to occur. If a pair of untwisted wires are run from a detonator, for even a short distance, along a rail carrying a varying current, and one wire is on one side of the rail and the other wire on the opposite side, or one wire is close to the rail and the other located at considerable distance therefrom, the circuit being completed by the generator, no insulation would prevent the induction of current sufficient to fire an electric cap in the circuit. I need not go further into the technicalities of this point. But I wish to add that immunity from such a danger lies in the use of leads well twisted from battery to detonator. And this is a precaution to which we seldom pay sufficient attention.

Wilfred Sykes: I would like to draw attention to one point in Mr. Clark's paper, where he says: " If the 37 men who were killed by electricity in and about the coal mines of the United States during the first eight months of 1912 had been the only ones killed in connection with the mining industry, effective measures to improve the electrical conditions underground would nodoubt have been taken immediately." I want to draw attention to the increasing attention that is now being given to the question of safety. Our steel mills at one time killed great numbers of men. In the last few years the people running the mills have come to the conclusion it is not very economical, and to protect their own interests they have given the question of safety a great deal of attention and spent a great deal of money upon it.

It seems to me that the number of accidents can be materially reduced by the work of the Bureau of Mines, if it obtains proper statistics and analyzes the causes of these accidents. The same thing is being done in other industries, and in this connection I wish to say—I am not quite sure of my figures—that about four or five years ago the number of accidents in steel mills in this country per ton of product was several times greater than they were in Europe, particularly in Germany. I understand at the present time, through the campaign which has been carried on, particularly by the electrical engineers, who have assumed the duties of safety engineers, that the number of accidents has been reduced until we have less accidents per ton of material produced than in Europe.

I think that the work of the Bureau of Mines, in which Mr. Clark has taken an active part, can materially reduce the number of accidents, by the collection of statistics, and by having proper regulations adopted in the different states. Perhaps, in that connection, we may some day see federal regulations controlling the mining industry, and then we will have a much better control over electrical work.

L. R. Palmer: May I ask Mr. Clark what is the method of testing the electric safety lamp as compared with the standard

safety lamp, and how you can determine their relative merits in that line?

The last speaker mentioned the work done by the electrical engineers in the line of safety. Perhaps it might be well to present to the Chairman of this meeting the report of the First Co-operative Safety Congress, held at Milwaukee, Wisconsin, September 30 to October 5, 1912, under the auspices of the Association of Iron and Steel Electrical Engineers, with headquarters at the Hotel Pfister. It was an electrical engineer who first suggested that this Congress be held, and it was Mr. Gano Dunn who was our chief adviser and assisted in drawing up the resolutions that brought into being the National Council for Industrial Safety. Anybody who cares to see a copy of that report can get it by writing to any member of the committee which was appointed to manage the affairs of the Congress.

George R. Wood: Referring to electrical accidents mentioned by Mr. Clark, the tendency is to magnify electrical accidents on account of the comparative novelty of electrical mining, and to lose sight of the general improvement in mining conditions, and reduction of the general hazard by its use.

For example, in 1911, Pennsylvania State Reports show 265 fatal accidents to 66,000 pick miners, or 4 per 1000. There were 127 fatal accidents to 55,000 machine runners, loaders and scrapers, or 1.3 per 1000. Had Pennsylvania's total output been mined by hand, total number of pick miners would be 136,000, with, on the same ratio, 544 fatal accidents, against 392 at present.

The same reasoning applies to haulage, where one locomotive, with two men, replaces 5 to 20 mules, each with a driver.

The increased output per man employed, resulting from the installation of electrical machinery, results also in decreased liability to accident, on account of the reduction in number of men employed.

Almost every mining district in the country today is short of men, and it would be impossible to operate in a large proportion of the bituminous districts without the use of electrical machines, locomotives and pumps.

Harold H. Clark: Mr. Bright spoke rather discouragingly of the use of storage battery locomotives. It was far from my intention to suggest that everybody should at once adopt the storage battery locomotive even for gathering, but I think it undoubtedly would be a step towards safety, and as such I mentioned it. I will further say that I believe that one of these days a practical storage battery locomotive will be developed for gathering.

Mr. Bright's remarks concerning the necessary staunchness of the construction of such a locomotive are well considered. Such a locomotive, and the batteries used to operate it, must be very strong, and very simple to operate. There are storage batteries, I believe, for which strong claims are made along these lines.

Mr. Dickinson spoke of the stray currents, and spoke of the possibility of detonators being discharged by induction in the leads from heavy currents in the rail. I do not consider this to be impossible, but at first glance it would seem rather improbable.

In regard to what Mr. Sykes says about collecting, classifying, and publishing the accidents that occur underground: That is something that is now done by the State Inspection Departments and published every year, usually about a year after the close of the annual period in which the accidents occurred.

The Bureau of Mines several months ago published Technical Paper No. 27, the title of which is "Monthly Statement of Coal Mine Accidents in the United States, January to August, 1912, with statistics for 1910 and 1911."

Mr. Palmer asked about the electric safety lamp test. In the Bureau's Technical Paper No. 47, just received from the printer, are given the characteristics of portable electric lamps as compared to flame safety lamps.

Schedule No. 5 just issued by the Bureau outlines conditions under which the Bureau will test electric lamps to determine their permissibility for use in gaseous mines. These conditions call for a high standard of design and construction. The electric lamp is so safe anyway, that any device applied to it to make it safer must be very nearly, if not quite, 100 per cent efficient, and the tests that we are going to make on those lamps is based on the fact that they should be nearly perfect. We shall take these lamps and try in every way possible to make them ignite gas, and then if we pass them, we shall be reasonably sure they are perfectly safe for use in any mine, no matter how gaseous. Experiments that are reported in Technical Paper 47 seem to indicate that sparks that may come from storage batteries up to a 3-cell battery, or 6 volts, will not ignite mine gas. If such a battery were short-circuited a spark that would ignite gas might be produced if the short-circuit current of the battery were rather larger than the ordinary battery would give, something like 100 amperes for a 2-volt cell and 85 amperes for a 4-volt cell. The only danger that the Bureau believes to exist in connection with portable electric lamps is the ignition of gas by the glowing filament of the lamp, and prescribes that such lamps shall be provided with safety devices, so that if the bulb should be broken, the circuit will be broken, or the lamp short-circuited, so that the carbon filament will not glow at a temperature sufficient to ignite gas.

DISCUSSION ON "MINING LOADS FOR CENTRAL STATIONS" (SYKES AND BRIGHT), PITTSBURGH, PA., APRIL 19, 1913. (SEE PROCEEDINGS FOR MAY, 1913.)

(Subject to final revision for the Transactions.)

P. M. Lincoln: I do not think in our industry there is anything on which the members of the fraternity have more divergent opinions than they have on this question of power rate. It is somewhat difficult in the first place to obtain a proper conception of the items to include, to arrive at a proper power rate. Possibly the best way to get at it would be to consider the things which go to make up the ideal power rate. In starting out on this task it is very possible, in fact it is almost certain, that what may be an ideal power rate in my opinion may not be an ideal power rate in the opinion of some one else.

In my opinion the ideal power rate should recognize load factor, it should recognize the power factor, it should recognize the quantity of power, and it should recognize the time of day at which the peak load occurs. In addition to these requirements, it should be easily measured, and measured by standard instruments one can get on the market, and by instruments which do not have an excessive cost. In addition to all that, it should be a rate which is easily explained to the customer.

When you have got that far, you can see that there are some inconsistencies, among the items that go to make up the ideal rate, because a rate which takes into consideration load factor, power factor, quantity of power consumed, and the time of day at which the peak occurs, is not easily measurable and also is not one which will be easily explained to the power customer.

We are, therefore, forced to the proposition of selecting a rate which will give the best compromise, and just what that compromise shall consist of is the point on which most us will differ.

The rate which has been suggested in the paper is, I think, an equitable one. It depends upon the maximum demand plus a kw-hr. rate, and a suggestion is made that the power factor should be taken into consideration, but just how that is going to be accomplished is not disclosed. I believe that a rate that is based upon the suggested method of measuring is an equitable one. However, the question of measurement is a difficult one. There are instruments on the market which will measure maximum demand, but they are not cheap, and as yet they have not had a very wide application, so that here again is a serious difficulty that confronts us when we come to this question of power rates. The demand for some instrument which will give us the maximum demand and possibly also take into consideration the power factor, will eventually result in the production of a meter which will be cheap and accurate, and will be standardized, but as yet I do not believe that we can now say that we have such an instrument.

Sidney G. Vigo: In the paper by Messrs. Sykes and Bright, on page 1014, under (b) the statement is made: "In addition to the above, a flat rate per kw-hr., based on operating costs, taking

into consideration the amounts of power used, and allowing a graduated discount to give large consumers a lower rate." I believe that this basis of charge is considered very carefully in Mr. Hopkinsen's design of his wholesale rate of charge, of which he speaks in the early part of his paper, that is, based on a kilowatt demand charged for fixed investment, and a sliding scale for the operating charges or the kilowatt-hours consumed per month.

Along these lines various central stations in the country have based a secondary charge, as it is called, per kilowatt-hour consumed, on such a sliding scale as ranges down. If a mine consumes, say 50,000 kw-hr., it gets a rate which runs down until it strikes about 6 or 7 mills per kw-hr. and below this sliding scale rate there is a still further discount given for prompt payment of bills.

Now, the central station, in addition to offering a rate of this kind, should take into consideration, as Mr. Lincoln suggested, the time at which the peak comes during the month. Where the central station is located in a large community, where it has considerable general business, and the business of the mine is only incidental to its general business, it may be considered that the mining operation is primarily off-peak business. They consequently should rectify their primary charge, or fixed investment charge, to conform to the investment required for the mine, which keeps off its peak. This should involve a different rate from that which is offered to the ordinary consumers, and the central station should be in a position to offer a very flattering rate to mine operators.

The matter of peak we know is of considerable importance to a central station company, not only during the summer months when the mine operates, but speaking of it in a general way. It might be shown that in one of the largest central stations, probably the largest, in the middle west, there are investments of $80,000,000 in equipment, transmission lines, etc., and during the summer months $25,000,000 of that investment is lying idle, and this large amount of equipment is installed to take care of the peak in the winter months; consequently, it has arranged very flattering off-peak rates to all classes of industries in order to improve its yearly load factor.

There is one point which Mr. Bright touched on in reading the paper, in the early part of it, which did not deal with the rate situation, but was a question of operating steam engines in mines. The fact that the engine was considerably larger than was required was due to the fact that there was no other engine available. That is quite a common occurrence in mines, as well as a matter of fact, in all classes of business, and it brings out very forcibly one of the strongest points that central station companies could use as arguments in favor of their service, and that is the flexibility of central station drive. As the mine will increase in capacity, or other machines are added to its equipment, it is not necessary to put in a larger unit—simply add

a larger motor; and in view of the contemplated growth of a mine, it is sometimes customary to put in a considerably larger engine than is required at the outset, and you can see that in this way the inefficiency at which a plant was operated during the earlier period might be quite considerable.

The central station company, although it is not its inclination to curtail the activity of the consulting engineers, maintains men who are thoroughly familiar with all classes of industries. The central station will have a man for instance, who will be an expert on mining, and he will give every attention possible not only to the securing of the business but also to the designing of the best equipment for the mine, and one of the prime slogans, you might say, of central station activity is the fact that after the piece of business is secured the work of the power man has only just begun. He must necessarily follow this piece of business and see that it continues to operate to the satisfaction of the consumer, and he should always be ready to offer any suggestion that will improve the economy of the operation.

Theodore Swann: I am connected with a company in West Virginia which is installing a plant in the heart of the coal fields, with the express idea of serving the coal mine load only. We tried to determine that ideal rate, which I know we have not done so far, but we have given the customers a certain benefit of the diversity. If a customer's demand is between 50 kw. and 300 kw., we determine his demand on the basis of a five-minute integrated peak, and set his circuit-breaker at 100 per cent overload, thus giving the individual mine the benefit of a 100 per cent overload, which will take care of any drop. If the demand is between 300 and 500 kw., if there is more than one line being operated by this customer, because there are very few individual mines that require over 300 kw., we lengthen the time out to 10 minutes, and only give him 75 per cent overload, instead of 100 per cent overload. In the case of a customer using 500 kw. and over, we stretch the time to 15 minutes, and cut the overload down to 50 per cent. In that way we believe we have every class of customer paying us the same interest charge. By actual investigation of more than one hundred plants in the field, we find the average investment per kw. of station capacity by the customer to be \$80. If we charge six per cent interest on that, and 7.5 per cent for obsolescence, as we prefer to call it, and 1.5 per cent for insurance and taxes, we have a total of 15 per cent fixed charges per kw. of rated capacity, which makes a rate of \$12 per year for fixed charges, independent of operating expenses, and we determine our rate on the same basis at \$12 per kw. of demand per year, to cover the carrying of reserved capacity for the operator. On tests made on fifty-six plants, which will average 200 kw. each, we found the integrated peak to be 60 per cent of the installed capacity, and that means the customers would be paying themselves on the basis of \$12 per kw. per year, but on the same number of kilowatts, only paying

us 60 per cent of that. They would have the 40 per cent, which means that is the reserve carried over the average of the fifty-six plants that we have tested on this basis.

As to the load factor, we found the minimum load factor based on the integrated peak to be 5.3 per cent, and the maximum load factor to be 49.7, and the average of the entire field to be 26.4, but the load factor based on demand to be only 15.8 per cent. These figures were determined by the printometer which we used on all the plants, conducting tests which covered from one day to ten days, in securing the average. We determined the average tonnage by the production for 1912, and during the time of all these tests we were " off " less than one per cent of the average normal production, so for that reason the figures may be taken as representing actual operating conditions to a degree which is measurably correct.

As to the diversity, by plotting the load curves of twelve plants we found the diversity to be 14.25, and taking twenty-two plants we found a diversity of 1.52. We figured originally we would have a diversity of 1.5, and instead of receiving $12 per kw. per year of demand we would receive $18 per kw. of our central station demand, thus enabling us to put more money than $80 per kw. including transmission, into our service.

From the present test, it would seem that our 1.5 diversity is going to be low. The 1.52 was based on the average of twenty-two plants, that aggregated 3,000 kw. of demand, and we expect to have on our line something like 20,000 or 25,000 kw. so that it would indicate, while the ratio is very much less as you increase the number of plants, that it will be possible to obtain a diversity, an hourly mining load, of at least 1.75. That is on bituminous coal, the majority of the mines being drift or slope mines, only about 10 per cent of our total output being shaft mines, and in that particular instance we measured the current to the customer at one point, and he carried it out to 18 points, so they get the benefit of the diversity before it goes on our line. If we had more of the hoisting loads, as you have in Pennsylvania, I do not think we could get the same results we had on that basis.

One of the most advantageous features to the mine operator in purchasing power, in my opinion, is to have a definite method of determining his cost. I have made the statement to some operators that we might charge them 25 per cent more per kilowatt-hour for current, and even at that we would save them money at the end of the year. At first that sounds more or less like a fish story, but relocation is our one hobby. The average power plant will lose from 30 to 50 volts in transmission from the power house to the drift mouth. In no case have we recommended underground substations. We want to simplify the operation in every way possible. This relocation means additional voltage on the machines; and in the case of one mine, which represented an average condition, which we tested, we

found that by improving the voltage, due to the bonding, they could haul twenty cars per trip in lieu of twelve cars. This condition in that mine was more of an average condition, rather than an abnormal condition. We have made the statement, and we have proved it out in actual test, that two locomotives or two mining machines will haul more coal and cut more coal than three locomotives and three mining machines, if you give the two locomotives and two mining machines good voltage and give the three locomotives and three mining machines ordinary voltage, not taking the worst condition. We have found some mines attempting to haul coal with as low as 40 volts. It is needless to say what the results were. It appears that the average power plant was installed somewhere near water, and as the mines grew and opened up their workings it was natural that the scene of actual operation in the mines became more removed from the site of the power plant, and our idea, in going into the field of supplying power for mining operations, is that the generation of current for mine use is becoming an alternating current proposition, though its use inside the mine may be in the form of direct current.

As to a uniform contract, the first thing we decided on was that we would give an absolute uniform contract and not vary from it in the slightest particular. I am glad to say we have over half of our plants loaded, and we have not made a variation of our rate in a single contract. We at first determined the form of contract which we believed was fair and equitable, and we have stood on that contract. It is based on the $12 per kw. of demand, and in addition to that a base rate for current supplied of 1.5 cents per kw., with a discount starting at 10 per cent and going in steps of 2.5 per cent up to 55 per cent. Our current charge runs from 1.35 cents down to 6 mills, based on the quantity used. The lowest discount is given on 10,000 kw-hr. per month, and the highest on a million kw-hr. per month. We have been able on these rates to obtain three of the largest operations in the field, and a great many smaller ones, and in practically every case we were able to show that, even on our rate, which we were very frank to state to the operator is high enough, we cannot give them strictly first-class service, and it has been my experience that the operator would rather pay a reasonable rate and be guaranteed good service than to buy something cheap; in other words, we say we are selling them service, and incidentally furnishing them with power. To carry that out, I may say that all of our construction will be steel towers, the poles all on loop circuits, and there will be no mine but what we can serve from two different points, unless it is a small branch off the main line; we will use 44,000 volts for our secondary, and when we develop a waterpower plant we may use something higher.

I have found that the operators in West Virginia are not after something cheap, they are after the most reliable service which they can obtain; they are installing alternating current

and properly applying it. In nearly every case that we canvassed the operators of the mines were more than anxious to get the facts about their equipment, and many of them said " we want you to please tell us frankly what you think of our conditions." Sometimes they have been so bad that we did not dare tell them frankly what we did think of them. I have dealt with the coal operators for about four years, and of all the different classes of people, I believe they are a class you cannot " put anything over on" and get away with it. You must have a fair, square rate, you may tell them you are charging them enough, but you must give every one of them exactly the same rate. I have known of cases where a salesman would sell one operator something at one price, and another operator the same thing at a different price, and it is only a question of days until that man's usefulness is done with in that particular field. I think that is true of the coal operators more so than it is with any other class of people. The inter-relationship and ownership between the companies makes it absolutely necessary to have a uniform contract. We have a new Public Service Commission in West Virginia, which, to a certain extent, has been the reason why we cannot make exceptions. On the other hand, when a coal operator believes he is getting the same contract as every other man, the tendency is for him not to read the contract, even. He will say, " Is this the same contract that so and so has?" And I will say, " Yes," and in some cases show the signature of the other man, and he will sign the contract and say, " If I am getting what he is getting, it is all right.'

H. C. Eddy: I think that Messrs. Sykes and Bright are to be congratulated upon the many good things that appear in their paper. There is one paragraph, which I think most mine operators ought to cut out and paste somewhere where they can refer to it frequently and become thoroughly familiar with it. That paragraph is this:

" It is immaterial whether the power is generated in a central station, and distributed to a number of customers, or whether each of the customers has his own generating station; the power cost will be made up of the same items, which can be very easily demonstrated to a prospective customer."

The only exception I would make to that is the last clause—it is not always so easy to demonstrate to the possible customer that he has any fixed charges. So many of them are apt to consider that the cost of the labor, the cost of the coal that they use, and the other incidental operating expenses are the only expenses that enter into the cost, and when you call their attention to interest on investment and depreciation, and some of these other items which are absolutely a part of the cost, they are apt to get back at you with the statement that the plant has long ago paid for itself, consequently no interest charge should apply, and they maintain the plant in good operating condition, and it is, therefore, not a part of their bookkeeping to make

any charge for depreciation. I think that if the average owner and operator of a power generating plant would consider these points a little more carefully than they have done in the past, that perhaps their ideas as to the cost of generating would be materially altered.

There is another point which I had intended to speak about, but which has been covered very fully by Mr. Swann, and that is the question of the primary charge based, say, upon a kilowatt of demand. The paper states: "It is usually not possible to arrange the fixed charge that a large customer pays so that it will cover the total fixed charges of the station." I do not consider that that is altogether necessary, that it should cover, because of the fact of the diversity factor that enters into a large system supplying power to a number of different customers, whose demands on that station come at varying periods, so that there is no great likelihood of one peak being superimposed upon another, and thus making unusual demands upon the plant and requiring it to carry a very high reserve capacity.

So far as I am able, I should like to endorse absolutely the remarks of Mr. Swann with regard to uniformity of treatment of various customers. That is the only way that it is possible to sell either service or a commodity. One man's money is as good as another man's, and so long as one man makes the same use of the facilities which the central station offers him as another one, these two men should be treated exactly alike.

There is another point I should like to bring out, and that is that it seems to me there has been an unnecessary discussion of the rate per kilowatt-hour. I do not believe that that is of as much real interest to the purchaser of power as the amount of his bill. I do not believe that there is an operator who cares very much what his rate per kilowatt-hour may be, provided the total cost of power purchased from the central station is less than he can produce the same quality service for himself, and whether your rate be 15 or 20 cents per kw-hr., and you can save him money in the course of a year, he is your customer for all time and your friend as well. So that while there is a great difference of opinion as to what constitutes the proper rate, and as Mr. Lincoln has pointed out, a proper rate, an ideal rate, from the central station standpoint, is usually almost impossible of explanation to the man who is not familiar with the problems of the central station, yet I think it is possible to incorporate all or nearly all of the elements of an ideal rate in such a way as to at least appear reasonable to the man you are attempting to deal with, even though he does not understand all of it, and that lends even greater force to what Mr. Swann has said in regard to uniformity of treatment of various customers. If they feel that you are dealing fairly with them, and that each man gets the same rate as his neighbor, and they will soon find it out if he is not, the question as to whether the rate is properly constructed and whether it is readily understandable, becomes a secondary matter.

S. B. Storer; The question of rates is one I have been considerably interested in for the last ten years, and I am glad to see that so many of the expressions of sentiment here this morning indicate a tendency to one system—that of a maximum demand charge plus a kilowatt-hour charge. If there is one thing that upholds the belief that that is the only fair system, it is a continual attempt to sell power for a number of years to all classes of consumers. Furthermore, all seem to realize the growing necessity of having an absolutely uniform contract. The feature of how the maximum demand is to be measured is one that every customer tries to settle to meet his own conditions, so that his longest peak will not be subject to that measurement. In all of the contracts which I have negotiated personally, the duration of the peak has been limited to 60 seconds. That may sound pretty short, but it might better be 30 seconds than 60 seconds, and it would still be equitable alike to the consumer and the power company.

To show, as an extreme case, that that is not too short a time, I can refer to one particular factory that I have in mind, a sheet steel rolling mill located near Buffalo where power is purchased on the basis of their load factor, the demand being on a one-minute basis. While the contract itself provided that the demand might be measured either by the average load for one minute or by a block peak for one minute, as obtained by a line drawing wattmeter, the measurement at first was made by a meter of the latter type. For a considerable period of time, the load factor month by month was determined at 125 per cent, or in other words, they never had a peak that lasted over 10 to 15 seconds, it being caused by a quick shoot of the metal through the rolls. The line-drawing wattmeter would make a momentary stab and drop down again. The result was that the sustained one-minute demand was simply the friction load—coupled with a small supply of energy to the flywheel, which, of course, smooths out the peaks a trifle. As a load factor of 125 per cent is an absurdity, the only thing that could be done was to call it 100 per cent and charge it on a kilowatt-hour basis.

The fair way to get at a demand charge is to arrive at a time element so that if it is in use over a very large system, the demand will be shown in the operation or action of the governor controlling the prime mover, whether a waterwheel, steam engine, or gas engine. If it is a momentary fluctuation, the stored energy in the revolving elements operating in connection with the transmission system will take care of it. A waterpower plant having a capacity of 100,000 h.p. will take a momentary demand on a railway system of 500 or 1000 h.p. and the governor may not show it, but if that demand lasts for 30 or 60 seconds the entire system is slowed down in speed sufficiently so that the waterwheel governor opens the gate to compensate for the extra load. To my mind, therefore, any system of charging to be equitable alike to the power company and the consumer

should take that feature into consideration. A steam plant can stand a peak of much longer time with safety, due to the stored energy in the boilers, than can any water plant which usually has no overload capacity in the wheel.

The fixed charge, as a proportion of the total cost, may in general be made considerably less with a steam plant than with a water plant, on account of the lower investment, but the kilowatt-hour charge must be correspondingly higher, due to higher operating costs. Twelve dollars per kilowatt-year as a fixed charge on a steam plant is fair to customers of almost all sizes, but on a water-power system, you must take into consideration the diversity factor to a much greater extent, and a user of 5000 h.p. should pay a great deal higher rate per horse power year or kilowatt-year, on the maximum demand, than the little fellow does. To my notion, the ideal system makes use of a low service charge per kilowatt-year for little consumers, perhaps of 5, 10, 15, 20 h.p., or even up to 50 h.p., and that may be $12 per kilowatt-year on their installed capacity or their contract amount of power, as they ordinarily require it, but if you put on a 5000-h.p. customer, your diversity factor is so cut down, that, as a general proposition, the rate per kilowatt-year should be 50 per cent more than it is to the small customer. Most of the contracts which I have negotiated take that feature into consideration and have a continually increasing kilowatt or capacity charge, from the smallest to the largest. To compensate for the increasing service charge rate, and also to meet the commercial conditions arising under actual operating systems, the kilowatt-hour rate for the small consumer is made perhaps 1.5 or 3 cents, while for the very large consumer it is only 3 or 4 mills, the service charge making up about one-half or even two-thirds of the total cost of power to the consumer.

I quite agree with the last gentleman who spoke that the average consumer does not care anything about the kilowatt-hour rate, provided his monthly bill is reasonable. While it is a statement of a somewhat retrogressive character, I am going to say that I think most of the tests to determine what the average manufacturing plant or any other power consumer uses, and what the bill is going to be, is pretty much time wasted. A good power salesman, with considerable experience, having a line of consumers with whose plants he is familiar, can tell what each plant ought to operate at, and if he has the courage of his convictions and believes it, and his power company has its nerve with it, they will go in and tell that customer— "We will equip your plant, supply it with power at our standard rates and you will run the plant with this power for a year. If at the end of that time the results do not appeal to you or you are not satisfied with the bills or service, you can discontinue its use and we will take the apparatus off your hands at what it cost you." I have used that same method repeatedly when it was impossible to convince certain manufacturers that their costs for electric

power would be within a reasonable limit. They did not care about that. They knew that it cost them very much less for power than the figures we mentioned, but they were willing that we should put in an equipment on the basis which I have outlined, and we have never yet been called upon to take back the apparatus. Service is the meat of the whole power discussion, and whether it is one basis of charging, or another, does not materially affect the consumer, so long as the result is satisfactory; but it is necessary, because of public service commissions, and because of swapping of stories back and forth between consumers, to have a power contract which is absolutely uniform for all of them, and you cannot get that by giving a five-minute peak to one customer, a fifteen-minute peak to another and half-hour peaks to others.

Graham Bright: I have not very much to say in closing the discussion on this paper. Mr. Lincoln made the remark that there was not an instrument at a reasonable price, available at present for making a proper record as mentioned in the paper, but it probably will not be very long until we can get instruments of this type. It is simply a question of time, because when there is a demand for a certain instrument it will be developed, and in my opinion it will not be long until we have instruments of the proper kind, at a reasonable price, to accomplish this service.

Mr. Vigo mentioned the difficulty of moving a steam engine around, as the plant grows, after the engine becomes too small and must be replaced by a larger one. It is quite a difficult matter to take the engine out and put a larger one in its place, but when the power supply is received from a central station, and the motor which the customer has becomes too small, it is a comparatively simple matter to slip a larger motor in its place, and use the smaller motor in some other application.

The question came up yesterday in regard to using the name-plate rating as the basis for fixed charge. There is a point in connection with this scheme which makes it rather a hardship for the customer. Very frequently in opening up a mine it is desirable to put in apparatus large enough to take care of the conditions in the future, and if the name plate ratings are taken as a basis for the fixed charge, it means that the customer is burdened with a heavy fixed charge until his apparatus becomes loaded. The result is he might buy apparatus entirely too small for his future needs, which will soon become overloaded, causing general dissatisfaction.

There is one question which has not been brought up in this discussion—Mr. Eddy mentioned it in his paper yesterday—that one of the first advantages to the operator from central station power was the decreased cost. Under certain conditions this is not always the first advantage and it is not always necessary to show an operator for a mine that his costs will decrease. In fact, I believe that in many cases an operator can afford to pay at least 10 per cent more for power secured from the central

station than it would cost him to produce it himself, due to the absence of *worry* and *care* and absence of investment, so that it is not always necessary to show the customer a decreased cost.

In regard to the policy of the central station with its customer, there has been too much secretiveness in the past and the general opinion of the customer has been that the central station is charging all the traffic will bear. It is only by an open and liberal policy toward the customer that the central station can obtain the confidence of the public, and the central station should stand ready to make concessions to a customer who is in trouble or has a long period of shut-down.

DISCUSSION ON "CENTRAL STATION POWER FOR MINES" (JENKS) AND "CHARACTERISTICS OF SUBSTATION LOADS AT THE ANTHRACITE COLLIERIES OF THE D.L. & W.RY. CO." (WARREN AND BIESECKER), PITTSBURGH, PA., APRIL 18, 1913 (SEE PROCEEDINGS FOR APRIL, 1913.)

(Subject to final revision for the Transactions.)

Graham Bright: Mr. Jenks has given us some very interesting historical matter. In the first part of his paper he mentions the early prejudice of the operators in regard to the purchase of central station power. I think this early prejudice was justifiable, when we consider that central stations had not made any records for themselves, and the operator had no way of telling what the continuity of service was going to be. As we know, in any new industry the pioneer usually stands the cost of development while those who follow reap the benefits, and you can hardly blame those early operators for having a prejudice against the use of central station power.

I think a great deal of credit is due to the operating forces of the central stations in bringing the continuity of service to such a high degree of efficiency. We have records of long periods of operation with little or no delays and records made by such companies as the West Penn Railways Co. have given to operators confidence in central station power, and have made the sale of such power a much easier matter than formerly.

There is one point I would like to bring out in connection with the paper by Messrs. Warren and Biesecker which has given us a great deal of valuable information on actual mine conditions, and that is, referring to Figs. 1 and 2, you will notice that the five-minute peak is considerably smaller than the integrated average for 10 hours. That brings up the point of just what kind of a peak to use on which to determine the fixed charge. This illustrates the fact that the block peak is not the proper one on which to base the fixed charge, because here is a case in which the block peak is considerably less than the average for 10 hours. You can see it is not a square deal to the central station to use a peak load which is less than the average 10 hour load as a basis for the fixed charge. It should be the intregrated peak rather than block peak, and these two curves illustrate that particular point very strongly. In fact a power circuit can be so manipulated that there will be little or no block peaks at all.

W. A. Thomas: Various statements of load factor, and particularly those brought out in the paper by Messrs. Warren and Biesecker, show the necessity of coming to a common basis in determining the expression of load factor. This is perfectly correct as explained by Mr. Warren, but unless you give a good deal of thought in transposing from one statement to another, we are led to confusion. In this case we have not only the load factor stated in terms of the average demand to the connected load, but we have the connected load rated on both constant and intermittent basis, and while, as I said before, it is perfectly legitimate and correct, we ought, in using it, to get to a common basis

of understanding. Of course, one statement of load factor is the ratio of the average consumption to the capacity of the sub-station. Another one is that which Mr. Bright touched on, the ratio of the average load to a given peak, five minutes integrated peak, or 15 minutes integrated peak. The point I wish to lay particular stress upon is the desirability of coming to a common basis for determining load factor and reducing the amount of labor necessary to transpose from one to another. I do not mean this as a criticism of the paper in any way. I consider that the data which is submitted in this paper is a most valuable contribution to the art, and one which will be of extreme value in this very active campaign on the part of the operators of central power stations in the coal mining regions.

J. Paul Clayton: The characteristics of coal mine loads as shown by this paper are extremely low annual load factors. The annual load factor controls almost directly the cost of producing power in any plant, such as the installation under discussion, and further to illustrate this point I have recomputed the cost presented in Mr. Beers' paper presented this morning, on the basis of lower annual load factors as they actually occur in these mines. In Mr. Beers' paper of this morning, the total cost of producing power in a station of 1000-kw. capacity, operating at 50 per cent load factor, was given as $35,000 on an annual output of 4,380,000 kw-hr. or a total cost of eight mills per kw-hr. Reducing this cost to the basis of a 20 per cent. annual load factor, which is rather high for mines with which I am familiar in Illinois, we have a total cost of $31,200 (about the only difference in the cost being the item of coal) and the total cost works out at 1.8 cents per kw-hr. Reducing this load factor further to 15 per cent, the cost of operation is reduced from $35,000 at 50 per cent load factor to $30,630, at 15 per cent load factor, or a total cost per kw-hr. of 2.4 cents.

In the operation of such a station for Illinois mine conditions, serving only one mine, on one shift per day operation, 200 days per year, you could not secure an annual load factor of 20 per cent. The load factor as I am using it, is the actual energy consumption in a year divided by the energy consumption which would have taken place had the actual 15-minute annual maximum demand basis been carried on throughout the year. This analysis shows that the probable cost of energy for the installation of the plant cited, when used under the conditions obtaining in the paper or under conditions obtaining in the bituminous mines of Illinois, would be in excess of two cents per kw-hr. instead of 8 mills per kw-hr. It would be perfectly possible to make power in that same station for about 6 mills per kw-hr. if you could obtain a 100 per cent load factor, but I believe the publication of such costs without adequate explanation of the effect of load factor on them gives a wrong impression as to the cost of producing power under the conditions obtaining in the vast majority of all coal mines.

George R. Wood: I think it important that we come to a better understanding of what we mean by the term load factor. In the course of this meeting we have had three or four varieties of this factor, based on connected load, station capacity, instantaneous, one minute and 15 minute integrated peak, etc. In other words, every central station figures customers' load factor as the ratio of average load to maximum demand, as defined by contract. It seems to me probable that an integrated peak over some such period as five, ten or fifteen minutes will ultimately become standard for determining maximum demand, but in the meantime a definition should accompany reference to "load factor."

H. M. Warren: If the gentleman who just spoke, contemplates using the figures I quote, as a basis of the kw-hr. cost, he should bear in mind that the information in the paper refers only to the direct current used in the mines in question, and that the large amount of alternating current power used, has not been considered. The load factor of our central station is 65 per cent, and is figured on the average yearly load in kilowatts compared to the rating of the station.

George H. Morse: It would be interesting to know how the gentlemen who made the calculations on their load factors proceeded in making these calculations. I think there are various ways in which individuals would proceed, and if Mr. Clayton would care to state how he made his calculations, I think we would be much interested in hearing from him.

J. Paul Clayton: As to the basis of the costs of power, I took the cost as given on page 838 of Mr. Beers' paper and assumed that, for practical purposes, the fixed charges remained exactly as given, and I think that is approximately true and that the item of coal, easily the largest single item, varied with the load factor. If we reduce the load factor from 50 per cent to 25 per cent, the coal consumption will be something more than half the coal consumption at the high load factor, as it does not fall off in proportion because the efficiency of boilers and turbines would be less.

In computing the cost given in my previous discussion I assumed that the coal consumption at 20 per cent load factor was half that at 50 per cent load factor and in obtaining the load factor at 15 per cent I have assumed that the coal consumed at the 20 per cent load factor was reduced by 15 per cent, and that the other items in the operating cost would be approximately the same.

C. W. PenDell: The item of load factor, as the Chair has said, is one that we should have a definite idea upon. It is something that should be settled and defined, and not a thing that one engineer should have a rule for talking on, in one line, and another engineer have another rule for talking on, in another line. If I design a plant to operate a mine and put in 1000 kw., and another man puts in 500 kw., that should not affect the load factor. The

consumption of the two plants will be the same. The load factor on the 1,000-kw. plant would be one-half what the load factor would be on the 500-kw. plant, if you base your load factor upon the size of the plant. Load factor is something definite, not something ethereal. It is the relation between the average load 24 hours a day and the maximum demand. You may take the maximum demand for five minutes, or you may take it for an hour, according to the way your contract reads. Whether you take a five-minute peak or a 30-minute peak, will probably make about 15 per cent difference in your load factor; that is, a load factor of 40 per cent on a 30-minute basis would be equivalent to 0.85 times 40 per cent on a five-minute basis. Load factor on a five-minute basis will be lower than on the 30-minute basis, because the maximum for 30 minutes will not be as high as the maximum for five minutes. Many base load factor on the operating time for the mine. According to the central station idea, and I am a central station man, the load factor should go over the whole 24-hour period. The reason for that is; supposing we have a plant which has 100 h.p. maximum demand, the average running load is 50 h.p. and the running time is 10 hours per day. If you base the load factor upon the hours during which the plant is running, you get a 50 per cent load factor. If the plant runs 20 hours per day, with an average load of 50 h.p., and you base your load factor upon the running hours, you still have a 50 per cent load factor. Under this method you have nothing on which to base a comparison of one plant as against another; so that in the central station field we have adopted the general ruling that load factor is the ratio of the kw-hr. consumption divided by the total number of hours in the period under consideration, and that result divided by the maximum demand as determined by the contract. To base the load factor upon the size of the installation is, according to my idea, erroneous. I may come along and install a plant with a 1000-h.p. unit—I do not know the business perhaps—I put 1000 h.p. in the plant to be safe; another man comes along who knows the industry, and puts in a 500-h.p. plant—why should the load factor of that plant, which is a concrete item, be dependent upon whether I know that line of industry, or whether I do not know it? Load factor is something which we can see if we stop to consider the curve. You have a certain curve running along with certain peaks in it; there is your load factor. It is the relation of the average line across the chart to the high point that constitutes the peak.

Graham Bright: I ask Mr. PenDell whether he has reference to the integrated peak or the block peak.

C. W. PenDell: The integrated peak is the only proper peak. Some contracts on railway lines, where the load fluctuates seriously, are based upon the highest instantaneous demand. It all depends upon the capacity of the station furnishing the load and the class of business you are serving.

I was talking with Mr. Jenks a few minutes ago relative to

mine hoists. He showed us a picture of a 750-h.p. haulage system. In Illinois we have mine hoisting outfits from 400 h.p. to 1800 h.p. We have not felt that we could take these hoists directly onto our lines, and have asked the customers to interpose flywheel motor-generator sets between the hoists and our lines. Now, with the flywheel motor-generator set we would integrate our peak. If we felt, perhaps, that we could stand the load directly on the line, we might give these parties contracts stipulating that the peak should be the highest swing of the needle on the chart. The integrated peak has been adopted in probably 90 per cent of all maximum demand contracts for central station companies. There are four common durations of peak, 5 minutes, 15 minutes, 30 minutes and one hour. Five-minute peaks have been adopted through the central states for coal mines and large stone quarries. Fifteen-minute peaks have been adopted by some companies for that class of business. General power is now being taken on over a great part of the country on 30-minute peaks. Railway contracts, large interurban systems, are going on commonly with 60-minute peaks. In addition to having the single 5-minute, 15-minute, 30-minute or 60-minute peaks, contracts are made wherein the maximum is based upon three 5-minute, 15-minute, 30-minute or 60-minute periods, no two of which periods shall be taken on the same day. That will, of course, give a lower maximum demand than a single peak.

George R. Wood: Perhaps we have no right to be surprised when the coal operator doubts our figures showing what he will get under these various rate schemes, and I cannot much blame the operators for refusing to buy power except at so many cents per ton of coal produced, and, indeed, power has been contracted for on that basis.

P. M. Lincoln: Reference has been made to 5-minute, 15-minute, 30-minute and 60-minute peaks. On the lines of the Niagara, Lockport and Ontario Power Company, which distributes power from Niagara Falls through Central New York, they have adopted the one-minute peak. I am inclined to think that for certain kinds of service measuring the current on a one-minute peak is more equitable than measuring it on any of the longer periods.

I want to say something about this matter of load factor. The writer of the last paper definitely told us exactly what he means by load factor, so that when we study his paper we have right before us what he means by the term "load factor," as he uses it. He is much more considerate in that regard than many other writers, because many writers use the term "load factor," and do not give data by which one can tell what they are talking about. Load factor, I believe, should be taken as the function of the load, and as having nothing to do with the size of the plant; in other words, I believe the definition of load factor as given us in the paper by Warren and Biesecker is not the proper basis for true load factor. I believe the proper basis for load factor is the

ratio of the average kilowatts during a given time to the kilowatts integrated through some definite shorter period; that may be one minute, 5 minutes, 10 minutes, 15 minutes, or any other period of time. It is the average for the whole length of time to the integrated value for the shorter length of time that should constitute the proper definition of load factor.

Then, again, the duration of the whole period is not necessarily restricted to 24 hours. We may have daily, weekly, monthly or yearly load factors and in general the longer the period the lower will be the load factor.

C. W. PenDell: This one-minute peak that Mr. Lincoln speaks of is more or less in the nature of an instantaneous peak. I threshed over in our company the question of how long a period we should take for the peak, and on our general power we adopted thirty minutes, for this reason: In studying a customer's load we say it will take 500 kw. to handle his entire requirements, that is, 500 kw. for the transformers. These transformers will stand considerable overload for a few minutes without damage. Our lines will stand the same overload. The generators will stand it. If we take a short duration peak period, the starting up of the factory in the morning, especially if there are a number of large motors, will have a tendency to boost the customer's peak beyond where we want it to go. We do not want the rates on paper to look excessively low. We would rather keep the rates so that they look reasonable on paper, and yet have the customer earn a low rate by having a maximum demand which is low, rather than to give him a one-minute peak which will make his maximum demand quite high, and charge him a relatively low rate for the maximum.

As the chairman has said, we can hardly blame the operators of the mines for not buying power when they find that we have all these different rates to offer. There is one thing that the power salesman must get the first thing when he goes out—that is the confidence of his prospect. The salesman must have faith in the commodity he is trying to sell the prospect, and he must know that when he figures out a rate for his prospect that the rate is right. On the other hand, we must also imbue the prospect with faith in the company, that he will secure equitable and just treatment.

The central station should not, according to my theory, sell at so much a unit output of the customer, because in so doing we are taking all the risk of inefficiency in the customer's operation. You go to one man and say' "I will give you current for so much a ton of coal mined," and you to go the next man and try to figure his cost and say "I will give you current for so much per ton of coal mined", these two men get together, and then the second fellow says, "Here, you are charging me 30 per cent more than you are charging the other fellow, what right have you to do that?" We try to explain to him that his method of operation is not the same as that of the other man, but you cannot explain

that to him. He has you, because he knows more about the coal mining business than you do, certainly more than I do, because I have not been in the business long enough, but if I tell them both "I am giving you the same rate per kw-hr.," and it is up to them to earn the same rate per ton mined if they can, they cannot accuse us of injustice, as they are liable to do if we try to sell them on the unit basis of output.

Sidney G. Vigo: The question of load factor is not only of extreme interest to the central station company, but also to the customer as well. The formation of rate schedules is for the purpose of giving to the customer a lower rate, corresponding to the increased hours of use of his maximum demand over any month. A customer operating twenty four hours a day naturally should receive a better rate than an eight-hour user. The schedules of rates that are designed, therefore, are inherently based on this idea of load factor.

It can be readily seen that if load factor were defined as the percentage of the actual consumption divided by the total horse power in motors installed, over 720 hours per month that the customer would be given a higher rate than if the load factor were the percentage of the actual consumption divided by the maximum demand, over a period of 720 hours per month.

This is made all the more evident in some central stations in the Northwest, where the rate per kilowatt hour is each month based on the load factor existing during that month. At the end of each month, the maximum demand, having been measured, and the consumption being obtained, the load factor for that month is determined, and the corresponding rate for that load factor is applied, and with each decrease in load factor, the rate is correspondingly increased. Therefore, with this schedule, if instead of measuring the customers' maximum demand, the total motors installed were considered, the customer's load factor would show a decrease, and he would pay correspondingly higher for his service.

This idea of actually measuring the highest demand of any customer is urgent oftentimes, because it is found that installations in large numbers of cases are made with the idea of future development, which we all admit is bad policy, owing to the inefficiency of the operation of large units underloaded, and consequently, a customer would be paying an unfair rate for service if his load factor were based on the size of his installation, rather than on his actual conditions. There are numbers of such cases that have come to the speaker's personal attention, but there is no doubt that many of you have experienced the same difficulties.

C. I. Weaver: There has been considerable discussion about theduration of themaximum demand, as to whether the integrated peak should be for a period of one minute, 5 munutes, 15 minutes or 30 minutes. This diversity of opinion led to the remark that the rate for power to the coal mine should be based on ton-

nage. The tonnage basis of rates is, in my opinion, very unsatisfactory. A comparison of the rates on the one-minute period, the 5-minute period, the 15-minute period, and the 30-minute period, would show the net power bills to be approximately the same for any given load.

Different lengths of periods for maximum demand readings are the results of different conditions in the central stations and widely varying opinions of rate makers.

It is not difficult, however, to estimate the cost per ton of coal from a rate having a demand charge and an energy charge. It would be descriminatory to base power bills on tonnage since the kilowatt hour per ton varies widely in different mines.

Our organization has for a few years been marketing power to mines with a rate based on 15-minute demand with additional charge for energy. It has proved fair to the station and satisfactory to the mine operator. The field of our activities has extended into Illinois, Indiana, and Michigan.

T. E. Tines: I wish to supplement Mr. Lincoln's remarks and the gentleman preceding, in regard to the load factor. I agree with them that the load factor is a function of the load and not of the installed capacity. I know of a certain plant in which, if the load factor was based on the ratio of the average installed capacity, it would be somewhere around 15 per cent, but based on the ratio of the average to the maximum demand, it is around 70 per cent.

I ask Mr. PenDell what method they use for integrating their 5-minute, 15-minute, 30-minute, and one-hour peak. In the company we take power from we used to measure the peak on a graphic instrument, a clear one-minute peak, and they had been working on that system for two or three years before going on the regular maximum demand meter, but finally did it, and that integrates the entire peak. We find that it raised our maximum demand from 8 to 14 per cent, depending on the nature of theload. We had to get busy, to counteract that and by generating our own power we brought our peak up to 93.1 per cent.

C. W. PenDell: In connection with the matter of measuring the peak, there has been developed in Chicago a meter for stamping the registrations of an integrating wattmeter. The train of gears on any standard wattmeter is replaced with another set of dials which have numbers on them. There is a tape which runs over the numbered dials, and a typewriter ribbon is placed in between. There is a clock which is set for 5-minute, 15-minute or 30-minute intervals, and as the contact maker goes around, it stamps the registration of the wattmeter dials, the same as if a man were standing in front of the meter and reading the integrating meter at stated intervals, only the clock does it automatically.

We used to have graphic wattmeters on certain loads. I found there was liable to be a discussion whenever it came time to decide on what the maximum demand had been. Every tenth

of an inch that the customer's engineer could screw me down on the curve meant anywhere from $100 to $1,000 to him, and I did not like to have him perhaps accuse me of trying to slide up a tenth of an inch, to make $1,000 for the company, so that I took them out and put in the other meter.

George H. Morse: Recently in connection with some properties in Minneapolis, I had occasion to study the conditions with reference to load factor as interpreted by the company. There we were using the actual maximum demands of consumers as registered on the Wright demand meter, the ratio of the average load being taken for the monthly load factor—that was all right in cases where we had non-inductive loads. Where we had an inductive load, as induction motors, in order to get the maximum demand in kilowatts, we were sending out men to make actual measurements on the customers' premises with wattmeters at such times as we thought we would strike the maximum for the month, and in this connection I will say that the man in charge of the meter department has a tradition that there is a certain company in the city there, a manufacturing company, that pays one man to sit at the door throughout the month and look for the man who comes to take that maximum demand—it is his conviction that, when he sees the meter man coming in the distance, he runs through the factory and gives a general alarm to the men at work, and the machines are drawn off throughout the factory.

That company was experimenting with the maxicator or printometer the gentleman refers to, an instrument for registering on tape the wattmeter readings. That instrument is the only instrument we can apply today to inductive loads to get the maximum demand kilowatt. The Wright demand meter is not of assistance in this case, because that registers the maximum current. That is what I want to emphasize and the reason that I rose. To my thinking it is not the maximum kilowatts that we ought to base our rates on, but the maximum current, after all, even in the case of inductive load, because we have to hold in our power station capacity for that maximum current, not maximum kilowatts.

C. W. PenDell: I am having carried on now some experiments on the measurement of maximum demand of inductive loads with the Wright demand meter. I believe there is some general ratio between the power factor and the maximum load of average size commercial customers. I want to put in the Wright demand meter, if possible, on a lot of these customers, to see if I can find a ratio between the power factor and the maximum.

Relative to charging customers for maximum current rather than maximum kilowatt, in our company all generators are purchased on a 75 per cent power factor basis. We put a 750-kv-a. generator—taking that as a unit—on a 500-kw. turbine, a 7500-kv-a. generator on a 5000-kw. turbine, taking fair care of the wattless current in that way.

Our operating department is trying to get the contract department to get our customers to put in synchronous machinery, so as to cut down the wattless current. We have taken the stand that we will not needlessly complicate customers' installations to correct the company's power factor, for two reasons: Whenever you get the customer to install expensive synchronous machinery to correct the company's power factor, they want a special rate, and special rates are something that we fight shy of. Another thing about the correction is, when you want the correction for power factor on your line the customer will have some reason for shutting down the synchronous machinery. You go to figuring on it, and the first thing you know he balls you up by not running it. I have told the operating department if they want power factor correction to put it in their substations.

H. M. Warren: While the tests which we ran on these substations were primarily for our own particular benefit, the results of these tests were urgently sought by a number of our companies, and I feel that with the data which were obtained and are available the central station man has all the information which is necessary, and a great deal more than he would have if he simply knew what the load factor was as outlined by the gentleman who has just spoken. One of the gentlemen stated that load factor was a definite term, comprising the average load, but from the discussion which followed I do not think it is. I have not been able to determine whether it should be based on instantaneous peak or on any peak up to thirty minutes. Therefore, it would seem to me that when the term "load factor" is used, it is necessary to qualify that by a statement explaining just exactly what is meant, in a manner similar to that which has been done in this particular paper.

DISCUSSION ON "ALTERNATING-CURRENT MOTORS FOR THE ECONOMIC OPERATION OF MINE FANS" (CROSBY), PITTSBURGH, PA., APRIL 18, 1913. (SEE PROCEEDINGS FOR APRIL, 1913.)

(Subject to final revision for the Transactions.)

C. W. Beers: The title of Mr. Crosby's paper is apt to convey, to my mind, something misleading. It deals with the motor side of the question and leaves out the fan side of the question, and I would like to give a few points in regard to the fan operation.

I have read the article by Mr. Crosby with considerable interest, as to me much of the subject matter as presented by Mr. Crosby is new. I was somewhat disappointed, however, to note the apparently small amount of attention that he paid to fans operating in the anthracite region, which, with few exceptions, require small driving power.

A survey of the fans in the anthracite region indicates that with few exceptions the fans are comparatively small. There are a few of 100 h.p., while the majority run below 50 h.p.

From the motor viewpoint of the article, as I have interpreted it, the application of variable speed motors as a fan drive is hardly the correct method of making use of the fan. Looking at it from the fan point of view, in the anthracite region I believe that the prevailing opinion of mining men is that the fan should run at its constant maximum efficient peripheral speed, regardless of the quantity of air to be delivered, although there are quite a few cases where this is not always carried out, due, no doubt, to certain peculiar property conditions.

Mr. Crosby has said that the great majority of mine fan installations require an adjustable speed drive. To this I do not agree unless the arrangements do not permit of splitting the air, or the air required is exceptionally small compared to the ultimate fan capacity, in which case I believe a better plan is to use a smaller fan until such time as a larger fan might be required. In the last paragraph on page 977 it is said that as the workings advance from day to day that the volume and pressure increases. This is not true. The volume decreases and the pressure increases, and if the fan is speeded up, to give more air, then pressure begins to increase at a great rate, with a considerable increase in power, and if that plan of operation is continued, then the limit of efficient operation is soon passed, the fan becomes inefficient, and the applied power is spent in overcoming practically resistance only, and very little is spent on the air, which is an uneconomical arrangement.

To produce a change in the air, by means of speed change appears to me to be rather bad practise, unless mining conditions prohibit any other method. It produces very poor fan economy, because the fan is not running at its most efficient peripheral speed. And on account of keeping so close to the air quantity, the gases may not be properly cleaned out, and it places the care of the fan in the hands of a person who may not, at all times, be under the direct control of the mine foreman.

On account of rapidly approaching the limit of efficient air volume, the fan becomes too small, or else the power apparatus is overloaded in overcoming the mine resistance. The correct way to vary the air quantity of a fan is by changing the air courses, or by splitting the current, thus giving an increased volume and a reduced water gage, and where this plan is carefully followed out, the fan runs at constant peripheral speed, and with slight variation in power. This also results in high fan economy as the applied power is spent more on the air than on the mine resistance, which is not the case in adjustable speed drives.

It is the displaced air that should be the measure of the power expended, and not the amount of resistance to be overcome. To illustrate this point: In a certain mine, the gangway was used as the intake, and the airway for the return. The water gage was two inches, the number of cubic feet was 98,000 and the fan was running at 50 rev. per min. It was necessary that the air be increased. To accomplish this the gangway and old airway were both made to serve as the intake, the headings being used for return. The result was that the fan delivered 178,000 cu. ft. of air, and the water gage dropped to 6/10 in., the fan speed remaining practically constant.

It is a fact that any normal size fan motor may be overloaded by reducing the resistance to a minimum, and working the fan on free air discharge. Conversely, the motor load decreases, when the fan displacement is the minimum, and the resistance is the maximum. Hence, between these limits the quantity of air delivered may be made anything, simply by varying the amount of resistance to be overcome, and as previously stated, this could be made by changing the airways themselves or by proper splitting.

From a consideration of these facts, it appears to me that constant speed motors are the proper style of drive to use, and should be used wherever possible. It is true that the ultimate variation in power on the motor may be large, but even between these extremes, the overall efficiency does not vary so greatly as the fan efficiency under these conditions is quite high and constant over a wide range in air quantity, provided the fan is operated at its most economical peripheral speed.

Mr. Crosby has said that reliability is the first condition, and then comes economy. As far as reliability is concerned, it seems to me that the simplicity of the ordinary squirrel cage motor could be well capitalized in the matter of economy, when compared to the more complicated adjustable speed drive.

Wilfred Sykes: I am very much interested in Mr. Crosby's paper, and I think it is well that this subject of using three-phase commutator motors for regulating induction motors should be brought up before a meeting of this class. In a paper delivered before the Institute in New York by Dr. Meyer and myself, a great number of other schemes were mentioned that have been worked out, using commutator machines. There are

a great many combinations possible, and some of them perhaps simpler than that described by Mr. Crosby.

I notice in Fig. 7, showing a regulating set, that it really consists of three machines, and apparently the small machine on the right is an exciter.

Now, there is one point I want to bring out particularly, and that is the question of the amount of attention that you can give to a mine fan or to mining apparatus generally. The usual condition in a mine is that you start the machine working and you let it go and hope it will keep going, and until something connected with the machine breaks, nobody goes near it. In my mind it is questionable whether you can use a machine having the characteristics of the three-phase commutator motor under those conditions and get good results. These schemes have been mostly developed in Europe, and recently I saw a number of them operating and apparently working very well. I asked the operators a number of questions, the principal one of which was—" How much attention do you have to give to the machine?" And I got the same answer in all cases, that they had to look after these machines pretty well, give them more attention than they would to a straight induction motor. If that is the condition existing in Europe, where they have a very much better class of labor, looking after machinery around mines, where the attendants are much better educated, and have a much better knowledge of the characteristics of the machines, what is going to be the condition in this country? It seems to me we will have to make our machines here very much stronger in every way to meet operating conditions than our European friends. I am convinced that for ordinary work you could not use the European induction motor and set it down under American conditions and get anything like the results achieved with the machines built in this country. Our operating conditions are different, and the machines have less skilled attention.

The question as to whether it is desirable to use any regulating arrangement at all is open to quite a little discussion—I am referring now to fan motors. My impression is that in most mines possibly two speeds for the fan will meet all operating conditions, or will meet the conditions with very little sacrifice in economy, if you consider the yearly operating conditions. Now, you can get the two speeds either by a two-speed motor, or you can have some arrangement in which you have different pulley ratios. The mine fan has to be belted in nearly every case, because the fan speed is so low that the motor could not be direct-connected. In opening the mine you do not require so much air, but later, you want to increase it, there is no hardship in changing the pulley ratio. A condition like that would not warrant, the installation of an expensive regulating set On the other hand, instead of the simple induction motor, you have, as shown in the sketch by Mr. Crosby, a three-machine regulating set, and I think when you come to consider, not only the first cost but the attention, and giving proper

consideration to the question of reliability, that there is quite some question as to whether you are justified in the majority of cases in using any scheme of this kind. I personally would very much like to see this thing worked out satisfactorily. On the other hand, I think we must go slowly in applying the European experience to American conditions. I know where it has been tried in a good many cases, and we have had disastrous results.

One of the schemes that was mentioned in the paper that we read in New York on this question involved only a single regulating machine, or, in case the voltage of the line was over 440, a single regulating machine and transformer. Such an arrangement seems to be a simplification of the one indicated by Mr. Crosby, but I think it will be a matter of some time before we can say that these equipments will be really satisfactory for American conditions. I think the experiment of trying out some of these things is one worth while, and such experiments may lead to developments which will greatly enhance the value of the induction motor and avoid the use of the direct-current variable speed motor around mines.

In all of our work in mining it is aimed to cut down the amount of direct-current machinery as much as possible, and try to use simple apparatus. Whether it is advisable to add on a regulating set, especially by a machine like the three-phase commutator motor, which has limitations, is a question which can only be found out by experience.

One point arises, and that is the use of the three-phase commutator motor on 60 cycles. Most of our mines use alternating current for 60-cycle power, and that makes it a good deal harder to make a satisfactory commutator machine than if we were using 25-cycles. Of course, the commutator machine is in the rotor circuit of the induction motor, and consequently the frequency on it is variable, depending upon the speed drop required. With a scheme of this kind the condition is not quite so bad, when driving a fan, as it would be if you had a constant torque, because the current decreases as your frequency increases, and that facilitates commutation. I think the question, however, as to reliability of these regulating schemes, is one that has to be given a great deal of attention, and one that makes it desirable to go a little slow in installing apparatus of this kind.

George R. Wood: My impression is that this particular application is not intended as a panacea for all ills, and that it is not expected to use this in those cases where we have fully developed mines, with fans requiring practically constant speed. There are conditions, as we all know, where we have to open a mine with very little air required. In a short time it will require a large fan operating at increasing speed. Mr. Beers suggests putting in a small fan and operating it at suitable speed, and later changing the fan. This is a waste. If we can install a motor which will do everything from the start to the finish

of the operation, and get fair efficiency out of it, it would seem to me to be very desirable.

One of the greatest difficulties in the application of motors to mine fans is this requirement for variable speed, and engines, even though wasteful of power, are often installed as a matter of convenience. It is always desirable to have reserve speed and power in mine fan equipment, which ordinarily means inefficiency under normal conditions.

I believe the regulating system described by Mr. Crosby to be very desirable on fan motors of 300 h.p. and over, particularly for bituminous mines, with high and rapidly increasing water gage.

I am glad to note that a number of sets of this kind are being installed by the Pittsburgh Coal Co., both of the motor-generator style for large motors, and three-phase commutator type for small sizes. These will all use purchased power, and valuable data should soon be available.

H. C. Eddy: I ask Mr. Crosby as to the expense attached to the use of the installation—the cost of installation of such a device—as compared with the cost of the main motor, not necessarily in dollars and cents, but in percentages.

Graham Bright: I would like some practical mine ventilation man, to tell us why we cannot run a fan at a constant speed at all times, and throttle the outlet of the fan? They do this in hydraulic work, and why can it not be done in fan work? Let the fan run at the same speed all the time, and then apply some arrangement of putting a throttle at the inlet to the mine, so that as the mine develops we can open up a little more and allow more air to go through. There may be some objections to this scheme, and some of our practical ventilation men may tell us what they are. The efficiency may be somewhat lower than obtained by some of the variable speed methods but the simplicity is such that the continuity of service should be very high.

Mr. Crosby says that sometimes an ordinary wound-rotor motor is used and speed reduction obtained by cutting a resistance in the rotor circuit and that this scheme is objectionable on account of the speed changing with the load. As to a change in load, with a fixed speed, this cannot be, since with a fan running at practically constant speed, the load is constant, and you therefore will not get very much variation of speed with any resistance you put in the rotor circuit.

I would like to know if there is any difficulty in constructing a three-phase commutator motor for 60 cycles, as most of the mine circuits have 60 cycles instead of 25 cycles.

Mr. Crosby also remarks that changing pulleys is rather in the form of a makeshift. When we start a new mine, and the mine develops and requires more air, it is not a question of changing the pulley every day or two. The fan will probably run for six months or more, before it is necessary to change the pulley, and preparation can be made beforehand, so that the

change of the pulley will not be a hardship and can be accomplished with little or no delay in the mine operation.

H. Meyer-Delius: I think there would be no question at all that we would use a normal squirrel cage constant speed motor if the mine operators did not want to change the speed, as the first speaker, Mr. Beers, said. I am not at all familiar with these ventilators or fans, and I am told that it is a very difficult problem to deal with. I spoke to several mine operators in Europe, and they came to conclusions contrary to Mr. Beers,' but I do not know whether that is due to different conditions in European mines or to different opinions about the same conditions. The usual conditions in Europe are such that at first when the mine is small they do not need much air, and since they are using a fan and a motor equipment of the full capacity they have either to throttle the pipe or to reduce the speed, and I am told that reducing the speed is much more economical than to throttle the pipe. They mostly run at first at 30 per cent less speed than at the end, and that means a very big difference for the air volume, and apparently they have found out that even at this low speed the fan operates at pretty good efficiency.

I had the opportunity to visit practically all of the installations equipped with such regulating sets, which amount to about thirty or more, and I have some figures which remained in my mind, which may be of interest to you. There are some five or six 1200-h.p. motors, 5000 volts, 50 cycles, with 33 per cent speed reduction, and a maximum speed of about 300 rev. per min., and four plants, of about 900 h.p., with the same speed, and 30 to 25 per cent speed reduction, some of 600 h.p. with the same percentage of regulation, and some smaller ones, among them one of 200 h.p

It was mentioned in this discussion that the average operator abroad is a much more trained and intelligent man than in America. I really do not know, if that is actually true, because the men I have found watching these plants could not be called intelligent men, they mostly were old miners, they would turn the hand wheels according to their printed instructions and had no conception of what happened, but they were apparently able to operate these fans. I must mention that all of these fans were so installed that the operator had nothing else to do than to start a normal induction motor, and the switching over from the starting resistance to the regulating set, was done automatically, so that the man had really nothing else to do than throw in the main switch and cut out the resistances of the rotor, and I think for this work really there could be employed rather unintelligent people.

Moreover I saw some of these fans running entirely alone, the doors locked, and I think once a day a man came over to see if all was right; so I think in Europe, these equipments with regulating sets are apparently developed to such a state that they are very reliable machines, and I have never heard of any

complaint of their being unreliable. As far as I could see there, the commutation was perfectly correct, which is, of course, the main trouble with these commutator machines.

From some mine operators I got the figures that they had to pay about three-quarters of a cent per kw-hr. to the central station, from which they bought their power, and that in about one year, the additional investment for the regulating sets was paid by the saving of current, and since the speed of these fans has to be reduced, three, four, or five years, they believed that that equipment was a very good investment.

Mr. Sykes mentioned another scheme, using a frequency changer, a single auxiliary machine. With the frequency changer there were also tests made in Europe, and as far as I know two of them were installed; one was a 600-h.p. fan motor, with 33 per cent regulation, and as far as I am informed this scheme was abandoned because they could not get the frequency changer to commutate at the lower speeds and that is my experience also, that is, that these frequency changers have entirely different commutation conditions from normal commutator machines, and it seems to me so far very difficult to get satisfactory commutation at least, at larger outputs.

W. O. E. Schmann: The statement has been made here that mine fans are usually put in operation and then not looked after at all, until something happens. I would not like that statement to be published in the PROCEEDINGS or go into the TRANSACTIONS, without making a defense, for the miners of Pennsylvania in particular. I have here a little book containing the Bituminous Mine Law of the State of Pennsylvania. It plainly states that each fan ventilating a mine must be provided with a recording gage that records the revolutions of the fan, or the pressure entering into the mine at all times, also that the fan must be inspected periodically. The provision is also made that in case anything goes wrong with this fan it must not be stopped, even for repairs, until the mine foreman has been notified, who, when he considers it safe, will allow them to stop that fan in order to repair it. In case the fan does stop, due to accident or otherwise, they are compelled to withdraw the miners from the mine until the fan has been made safe. For that reason, a great many companies have two fans, one in operation and one in reserve, so in case anything goes wrong with either fan they can immediately put another fan into operation, and there is quite a stiff penalty attached to any violation of this law.

B. M. Fast: In the territory I cover I find that the fan requirements vary from 25 to 50 h.p., and in no case have I found them larger. Up to the present time, most mines are operated single shift, but since they have been buying power the question has arisen of operating double shifts, and thereby saving in cost of operation. That time is coming, and even now the operators are talking of developing the mines and running

double shift. During the night shift only 25 or less percentage of the men are underground, as in comparison with the day shift, and therefore it is not necessary to have as much air during the night shift. The question arises: can we not save the operator a certain amount of power cost by a change of speed of the fan? If it can be done, the central station man should have the credit of doing it, if it is possible, because the operator is only too glad to save in his cost.

In matters of this kind it seems to me there is only one of two things to do. First, as to the question of buying power for a new mine, I simply change the pulley speeds and it solves the problem but for a mine that has been developed and wants to run cutters or pump men under ground at night, I would rather have a split ring motor, with external resistance, or a two-speed motor, doubling the number of poles for the lower speed.

The next question the operator asks is, which of these it is more advisable to install and operate. If the two-speed motor is simpler and has fewer parts to get out of order, and these fans will run without attention, they naturally prefer that motor. The two-speed motor may be less complicated, and there may be a saving in power, as compared with the variable speed motor, yet the cost is very much higher.

The next question I submitted to manufacturers was with reference to variation in speed between full speed and half speed. The result I found was that there was not 5 per cent difference in half speed operation on the two-speed and variable speed fan motors. Whether or not the data submitted to me by these companies is reliable, I am not in position to say, but it showed less than 5 per cent difference in the amount of power used. So that from my experience the two-speed fan motor is preferable, rather than the variable speed, due to the fact that the simpler construction requires less attention. In this particular case it was a 40-h.p. motor, variable speed, requiring on half speed of the fan something like 15 h.p. The data on the two-speed fan showed that it required 15 h.p. on half speed. It is simply a question of which motor you want to buy in that case. It seems to me that will apply to the territory I covered.

H. L. Beach: I had occasion some four or five years ago to purchase a fan and motors for a mine where we were doing developing work to a considerable extent. The exact figures of the amount of air required have slipped my mind now, but I know that we needed a total of 200 h.p. to operate the fan at full capacity. At the time the fan was to be installed they needed possibly only one-third of that. My purchase consisted of two squirrel cage motors, manufactured at the same time, so as to get the characteristics identical, tested and guaranteed to divide the load equally at the same speed. When tested the motors were fastened together with a flange coupling, and the load driven by a belt using the coupling as a pulley, the load dividing within a per cent or so between the two motors. I then set one motor

on some temporary work we had, and put the other motor on the one fan. That motor has been running something like three years, and they have not had occasion yet to change the pulley. The arrangement was that we would make a high pulley ratio to start with, and as the requirements for air increased they would decrease the pulley ratio and speed up the fan. The arrangement has been absolutely satisfactory, and not given a moment's trouble or delay in any way, and so far they have all the air they want with one motor and the original pulley layout. It is ready at any time to put another pulley on. They can make one increase in speed with the present motor, and then by releasing the other motor they can increase the speed until the full capacity is obtained. I can, for my part, see no reason for the large expense and complication of variable speed outfits. The change in pulley is not a proposition which comes up every day, but a proposition which may come up only once in two or three years. Two or three fans are usually required for a large mine anyway and it is a simple proposition to shut down one or more at night and run all during the day.

F. B. Crosby: The discussion aroused by this paper would appear to be ample justification for its presentation. The particular point about which the discussion has chiefly centered, namely, the desirability of adjustable speed drives for mine fans, was taken for granted by the writer. As stated in the paper there is a somewhat limited field in which constant speed drives are satisfactory, but the very great percentage of requests for adjustable speed fan drives as compared with constant speed applications which have to come to the writer in his professional capacity, as well as the ready defence of the adjustable speed drive by many experienced mine operators and engineers this afternoon, can leave no doubt as to its desirability.

The method of obtaining speed control by dynamic regulation as described has been developed to meet an existing need. These speed regulating sets and brush shifting motors are the result, and not the cause, of the demand for adjustable speed drives. The entire range of horse power capacities and speeds ordinarily required can be simply and more efficiently met by one or the other of these two equipments than by any other commercially practicable drive yet devised.

For small drives, 100 h.p. or less, the extreme simplicity of the brush-shifting motor and control is especially desirable since the single motor involved is started, stopped, reversed and the speed controlled by merely shifting the brushes.

It has been suggested that the regulating set introduces a complexity of control equipment prohibitive in the hands of the average fan attendent. This feature has, I believe, been unduly emphasized.

Considering the results obtained nothing can be simpler than the operation of the set. The main motor is started in the usual manner by simply closing the primary oil switch and throwing

the controller to the full-on position. The motor generator is started by means of a standard induction motor compensator. Electrical equilibrium between the main motor and motor generator is absolutely automatic. Any desired speed of the main motor within limits of design is obtained simply by adjusting the exciter field rheostat.

Referring to Mr. Eddy's request for information regarding costs, it is difficult to answer such a question, except in general terms, owing to the many variable factors involved. The cost is obviously more than for a single-speed motor and depends upon the frequency and range of speed required. For 25-cycle equipment designed to give 20 per cent speed regulation on the main motor, the complete equipment including main motor and control may cost from 15 per cent to 20 per cent more than a two-speed motor designed for the upper and lower speeds.

DISCUSSION ON "INDUSTRIAL EDUCATION" (REPORT BY EDUCATIONAL COMMITTEE), COOPERSTOWN, NEW YORK, JUNE 24, 1913. (SEE PROCEEDINGS FOR JUNE, 1913.)

(Subject to final revision for the Transactions.)

Charles L. Clarke: The five papers upon education which have been read this evening relate to industrial education directed toward the improvement in efficiency of the workmen in the various industries and the minor technical men connected therewith, all generally definable as laboring men, nevertheless of widely varying degrees of intelligence and skill. Hence, it is, specifically, vocational education.

The purpose is to make such men as a whole intelligently skilful in their calling, and therefore, more useful to their employers. Incidentally, it will result in a few men, with greater natural talents and force of character than their fellows, advancing from the ranks to assume executive positions of greater or less importance. Furthermore, as mentioned in the paper by Prof. Norris, it will undoubtedly vastly improve the relations between labor and capital to their great mutual advantage.

It is not the speaker's purpose to traverse the matters relating to vocational education that have been presented in these papers except in one particular. The details can, obviously, best be handled by professional educators, who make a specialty of these lines of training.

Now, to the point that the speaker has particularly in mind— it is the teaching of good English composition, which has been referred to briefly in the papers by Mr. Rowland and by Prof. Jackson and Mr. Hale. Along with the study of matters vocational and cognate subjects, the study of English should diligently be pursued throughout the entire course, not merely in a formal way, as determined by the educators, but through notes and examination papers handed in at frequent intervals, which should be corrected by the English teacher and instructively commented upon before the class. Proper improvement and perfection in composition should be insisted upon, on a par with proper advancement in other studies.

Digressing for a moment from strictly vocational education, the study of English should be insisted upon in the student courses for graduates of technical colleges, which are now pursued in the works of some of the large manufacturing corporations. Deficiency in ability to write good English (which includes, of course, correct spelling) is nowhere more apparent than among young men just out of college, and this defect does not wear away any too rapidly with the progress of the years.

It is a serious handicap to them, and especially to skilled but uneducated artisans, who are liable keenly to feel this defect which the speaker has often observed, like a weight bearing them down and making it appear to them useless to try to rise above the lower level in which circumstances have placed them.

Drill the artisan in good English, make him conscious that he can talk and write with respectable correctness. It will conduce

to clearness and conciseness of expression, which are most important adjuncts; will help discipline his mind and make him a clearer thinker, besides increasing his self-respect, all of which will make him more valuable to his employer and also to himself.

A professor of rhetoric in Harvard University has stated in his text-book on the subject that although there may be good English there is no such thing as perfect English. Therefore, an effort to reach the unobtainable may not be made; perfect English is practically out of the question; the English of the scholar is unnecessary; nevertheless, ability to speak and write passably good English should play a serious, substantial part in vocational education.

Henry G. Stott: It seems to me the keynote of the whole situation in regard to industrial education occurs just in a single sentence in the paper by Prof. Jackson and Mr. Hale, with which I heartily agree. It is as follows: "It was, therefore, very carefully determined at the outset that the apprentice school work should be so given as to develop in the young men a proper ambition to become skilled in work of this character and at the same time to avoid developing in them the discontent and unhappiness which comes to those whose aspirations are beyond their capability or circumstances—as would be the case if they were led by their instructors to believe that they should attain positions in which manual skill and labor is not required."

It seems to me that is the keynote of the whole situation and it points to a grave danger in this so-called trade school and industrial education by corporations. The company with which I am connected has done a good deal of this work, but we do it mostly with a view of finding out what the men know, so as to be able intelligently to select men for promotion. We fear there is a very great danger, as noted here, of storing up in men false ambitions and false ideals such as that it is not quite as honorable or as reputable for a man to work with his hands and have a suit of overalls on, as it is to have a clean job as a clerk at $50 or $60 a month, and there is a tendency, especially with the young foreigners, to set up these false ideals as to the value of education.

I do not wish to underrate the value of education, because no one can get too much of it, but a great many of our high schools seem to teach wrong ideals in many cases, and I believe the whole secret of success is in finding out which of the men are ready for promotion, and which of the men really deserve to be promoted, and not in the attempt to give them a smattering of instruction in a few subjects. We know, when it comes to engineering work, that we must have men who are thoroughly trained in the fundamentals of physics, and we select our engineering group from college men, as in the company I am connected with, but before promoting our men to the minor positions of responsibility we use the training schools to find out which of the men are thinking seriously. Perhaps once a year we find a man who should be encouraged to try to work his way through college, and we help

him all we can. Three or four men in the last three or four years have made very creditable records, but that is a very small percentage, probably less than ¼ of one per cent of the employees, so that I think the point of view announced here in the paper by Dr. Jackson and Mr. Hale is really the keynote of the whole situation—that we must be careful not to store up false ambitions in a man who is incapable of being promoted, because he has not the ability or the necessary education, and it is distressing to see him become discontented and unwilling to work at honorable trades at which he could earn three or four times as much as a clerk makes. The result of this dissatisfaction is that he goes out into clerical employment, and he finds that he is in the midst of a host of competitors for what he calls a clean, respectable job.

M. T. Crawford: In my connection with the public utility company in one of the Western Cities, I have found that there are many young men at work during the day in the city, who would like to study further. I would like to bring out in a little further detail the work which is accomplished by the universities in some of these far Western cities.

The University of Washington, in Seattle, for instance, gives a course in electrical engineering covering four years leading to the degree of B.S.E.E. and with the fifth year giving a degree of M.S.E.E., and after three years in a responsible position the degree of E.E. is given. In addition to this regular college work night classes are held for advanced study and research work by technical graduates who are engaged in practical work during the day in the city. Separate night classes are also to be given this coming year of a more elementary nature for men who have not completed the University courses, but who have met the requirements of the University, who have to work during the day. The latter are standard courses and University credit is given for the work. A considerable amount of special work has also been done by the regular students from time to time for the larger companies, such as oscillograph tests and special research work, which gives them a direct practical contact with operating conditions.

J. W. L. Hale: The apprentices serve four years and are moved from one department to another as stated in the paper. This is done so that they may have a varied experience. We feel that we lose nothing by giving them a broader idea of the work in the several departments of the shop as well as that in which they are more directly interested. Many of these apprentices will ultimately be called upon to fill positions of minor responsibility in shop management, and therefore this knowledge of other departments is necessary.

I might say along the line of the questions which have been raised that apprentices, when they go into the school, have open to them all of its privileges and they are bound to make improvements along general lines. However, the matter of education of apprentices, as it appeals to us largely, is in regard

to developing their powers to comprehend instructions which are given them and to make reports properly, etc., etc. You appreciate the necessity of this in the operation of a railroad. It is necessary that they have such a knowledge as will enable them to understand instructions and make reports intelligibly.

Regarding the aspirations of apprentices for something higher than that for which they are suited, I have spoken of our schools as selective media. The boys who come to us are of all grades of ability, and it is for us to line them up and put them into that part of the organization in which they properly belong.

So far as our experience extends the boy has not become dissatisfied with his condition through the fact of further instruction. We think a great deal depends on the instructors as to the ideals which they put before the boys. If they teach them the honor of labor, and instill in their minds that, by attention to their duties, promotion is open to them, and that some of the railroad mechanics earn more than professional men, it seems to me that this difficulty can be overcome to a large extent.

The Pennsylvania Railroad is only one which has taken up the matter of an apprentice school instruction system. There are at least eight, and possibly more, representative roads that are engaged in the same work. These extend from the Atlantic to the Pacific, and the work is progressing very rapidly. This is one of the principle features of work which is being taken up in the new organization, the National Association of Corporation Schools. The matter of corporation industrial education is not new but is well afield.

J. Lloyd Wayne, 3d: I believe in all matters of this kind the difference between success and failure may lie in the local traditions of the community in which you are situated. For instance, in the East, where both a man and his family will undergo considerable personal hardship to give him an education, you can go a great deal further in this matter of education than you can in a community where practically none of the families will undergo any hardship to have their young people go beyond the education which is required by law. If you try to introduce industrial education or similar activities amongst people of that kind, you are apt to run up against this condition which I have seen,—many of the men will feel that to join these classes gives them a pull to get ahead. Some of them do not, of course, but I have known of a school where it was discovered a large majority of the pupils attended with that motive in view, having no motive for attendance except the standing which they felt attendance at the school gave them with the boss. They really did not get much out of it and the school was abandoned.

This state of mind on the part of the pupils was found to be not exceptional, but quite general. One whose experiences have been gained in the East exclusively is likely to overlook the fact that in a relatively young country there is not much ambition to secure an education, and more people are satisfied to work along a

certain number of prescribed hours, and have their endeavors end with that, rather than to take up any additional work in the form of study.

A. M. Buck: Although we have been talking this evening almost entirely about instruction, I think we have forgotten the instructor. In any scheme of industrial education he is one of the most important factors, and a careful choice should be made to secure the proper man for the work. In the college or university the instructor is often chosen because he was a good student, and perhaps has done excellent work after graduation. This, of course, gives no indication that he has the proper personality, or that he is especially fitted to instruct others. In some cases he may succeed, especially if his work be along the lines of research, where he does not come into intimate contact with students. When, however, we consider the choice of teachers in industrial or trade schools, I think the personality of the instructor is of vital importance, and believe that it is absolutely essential to choose men for this work who are in close touch with the situation. Furthermore, they should be able to inspire the men in their charge. I have had but little experience with vocational training; but I do know a number of college professors who have given inspiration to their students and brought out a great deal more work from them than is ordinarily obtainable.

Another point which comes up in this connection is the training of the instructor. In many cases he is simply turned loose on his work without having had any special training, and often without definite instructions of any kind. The necessary training is not given in many of our technical schools, but I believe it should be. At least the instructor should be told exactly how to go about his work to produce the best results. I think many instructors who might be very successful fail because of their inability to appreciate the situation. Had they been properly directed at the beginning, and understood thoroughly the proper attitude toward the students, as well as how to impart their knowledge, much good might have resulted both to themselves and to their students.

F. C. Caldwell: Much has been said this evening about the value of vocational training as given by industrial concerns, as a help in the selection of men to do the work for which they are best fitted. The two aspects which this work seems to take on are these: first, the work of the industrial concerns in training their own men, and second, the work of the universities and other institutions in training those who either are not yet connected with any manufacturing concern, or in training those who are so connected during their spare time. There is one point, that I was glad to hear Mr. Stott speak of and which needs to be emphasized; that is the importance of being on the look-out for the unusual case, for the ¼ of one per cent, that is for the man who ought not to remain a mechanic, but who ought to be encouraged to go ahead and secure a college training, so as to become an en-

gineer and a leader. We need all of this type of men that we can possibly secure. The supply now is not equal to the demand. It may not be generally known that the supply of college-trained engineers is decreasing, while the demand is increasing; that throughout the country the engineering colleges have not been increasing in the number of their students during the past four years and in many cases they have actually decreased. This is largely due to the growth of the agricultural colleges and general development of the agricultural movement. We therefore need in our engineering colleges, all of the men that we can possibly get, that are of the right kind out of which to make engineers. This is one of the things which vocational traning in industrial concerns should accomplish, the picking out of the exceptional man, who is just the man to send through college, to receive a course in engineering, and to be turned out as a competent engineer.

The other point is the work being done in the line of vocational guidance outside of the industrial concerns. There are, as you may know, societies in many of the larger centres whose object is to study the subject of the vocations in which the boys and girls may engage, and to try to guide them into those vocations which will give them the best use of their abilities and yield the greatest return to society from the results of their endeavors. We know that there is a tendency for the boy, when he leaves school, to pick up some stray job like selling tickets for a moving picture show or something of that sort, which will yield him some money immediately, but which leads to absolutely nothing in the future, and the object of the vocational guidance societies is to try to educate the school children into the idea of looking forward to their life's work and planning for it, even before they have left school. It seems to me that this is a very important feature of this work which our committee might do well to consider.

H. M. Friendly: There is a phase of education which I think has been sadly neglected in colleges and in various institutions of learning, and that is encouraging the students in the reading of technical magazines and periodicals. You cannot impart experience to a man, but you can impart knowledge to him in various ways—by reading periodicals and other literature, and reading the experiences of men who have superior ability to observe phenomena, etc. A man will often get in touch with practical matters, and gain a degree of experience in reading about them, possibly better than he might by actual contact with the work. With all due respect to the colleges, I have had occasion to observe that the men they turn out, or at least most of them, are deficient in that one thing, and I also find that many of the men that come out of the colleges and other educational institutions because of their failure to read technical literature fall by the wayside.

Mr. Carron: There are two or three points upon which not enough emphasis has been put in the discussion of the papers this evening, and one of these points is, in order to make real progress in educational matters the fundamental principles of educa-

tion must be applied to these vocational courses just as they are to the more advanced courses, and a great deal of the fault in the past with vocational courses, which have sprung up here and there, is because they have not been carefully organized, have not been put in charge of men who have made a study of educational problems, and the result has been these various deficiencies which have been pointed out. In one class the instructors try to instill too great an ambition in the minds of the students, and succeed in getting them discontented with their particular line of work and more harm than good is done. In another class the instructors do not appreciate the advantage of picking out the occasional individual and giving him the personal instruction which isneeded; but the fact that a group of papers of this sort is brought up for discussion at a meeting of this nature and the fact that more attention is being given to the subject along these lines is encouraging to us who are interested in educational problems.

George C. Shaad: I wish to take some exception to the points brought out in regard to the matter of the care now being taken in selecting instructors in all classes of educational work. I believe the personal side of the instructor is receiving, in the better grades of institutions, as much, if not more, attention than the purely theoretical knowledge which the particular candidate may possess. It is only by securing coöperation and one institution profiting by the failure of another that much can be done through these organizations for industrial education, and if these institutions will profit by the failures of the past as much real progress in this line as in any other line of education can be made.

O. J. Ferguson: There is an unfortunate thing which develops in the course of the instruction of college classes, and that is that some 30 per cent or perhaps 50 per cent of the men in the classes ought never to have gone to college. I believe that one of the most encouraging features for those who are taking up the matter of vocational training is to be looked for in the possibility of the selection of our raw material. I believe that if we were able to make the selection of the raw material when it comes to us, rather than taking a great deal that should not be allowed there, the results that are attained from college education would be greatly improved as well.

Comfort A. Adams: My interest in the subject before us is not so much that of the professional educator as that of the citizen and engineer, and the point I wish to make relates to certain broad aspects and ideals of social and educational efficiency.

In the youth of our country we have the raw material which undergoes some degree of refinement and adaptation to useful ends, in our various educational institutions. The varieties are only limited by the number of individuals, some are fitted by nature for one life task and some for another. To make the most of this raw material is the problem of education, and the degree in which we succeed in wisely *sorting* it and then in *developing* it in each of the numerous fields of service to its maximum

usefulness, is a measure of the real efficiency of our educational system.

The problem of developing such material as now comes to our various schools and colleges, and the increase in the variety of fields in which education is offered, are common subjects of discussion, but it is to the subject of *sorting* that I wish to call your particular attention.

For the purpose in hand let us divide the youth of the country into two groups: one group including those to whom the higher or professional education is now open—less than 5 per cent of the total—and the other group constituting the remaining 95 per cent. Some may disagree with my figures and say that every really strong young man has this opportunity if he is willing to work; but such are the rare exceptions and I am talking of averages. If the rare exceptions were alone to be considered, the problem of education would be a simple one. Actual statistics will show that my 5 per cent is a very liberal allowance.

Within this small group there are many who are not able to profit by their opportunities and who are, as a result of professional training, actually unfitted for occupations more adapted to their native ability, such occupations being considered beneath a college man. On the other hand, there is undoubtedly much material in the larger group well able to take full advantage of the highest educational opportunities, but prevented from so doing by no fault of its own. All this is a great burden upon and loss to society, a burden in attempting to instruct the unfit, and a loss by the waste of much good material sent out into the world without appropriate training. A young man's college tuition fee pays ordinarily not more than one third of the cost of his instruction the other two thirds is contributed directly or indirectly by the community at large, except in the case of state universities where *all* of it is so contributed. Thus all of those young men who are not profiting fully by this training, who are not being really educated (and this number is not small) are burdens on the community, even though they are paying tuition.

The industrial training here under consideration, is a good thing because it offers to those in one group an opportunity to increase their efficiency within that group, but it does not fundamentally change the situation or touch the root of the real difficulty. It does not appreciably increase the opportunity for the passing from one group to another better adapted to the native capacity or ability of the individual in question, it does not appreciably improve the "sorting" process.

I grant you that this difficulty is a fundamental one and that it is entangled with the very roots of our social order, but it is well occasionally to realize the defects of that social order and to turn our eyes towards an ideal if one is available. The nearest approach to a solution of the problem lies in what might be called the competitive system of education, in which the degree and variety of education open to any individual is *wholly* dependent

upon his ability to profit by the opportunity, as determined by competition. (I here use the word "education" in its narrow rather than in its broad sense). A somewhat distant approach to such a system is now in operation at West Point and Annapolis. Under our present social order, educational opportunities beyond the legal requirement of a primary schooling, are largely dependent upon the length of the parents' bank account. In other words, the present basis of "sorting" our "raw material" is most crude and irrational.

Mr. Stott speaks of the danger in the proposed system of industrial training, that some young men may be educated beyond their ability to make good or to profit by it. This is exactly what I have tried to point out in connection with our present system of higher education, except that it is vastly greater in the latter case owing to the fact that many men are in college largely because of the money back of them, whereas, the men in the various industrial or apprenticeship courses are usually on their merits. It has also been stated that men attend these courses in order to "stand in" with their employers or bosses. A boss not able to judge of a man on his merits is hardly fit for his job. But in the college this becomes a real danger. A boy from a well-to-do family is sent to college and is made to feel that he must follow some "profession," when in fact he is not fitted by nature for any of them. He may be a good mixer, he makes friends and connections in families of wealth and is boosted and pulled along into positions which he fills with little satisfaction to himself or anyone else, while thousands of men with the ability and character which he lacks, are wasting that ability and making poor manual laborers for lack of educational opportunities. This all means social waste and inefficiency. We too rarely stop to realize that the more nearly each unit in a social group can be developed to its maximum usefulness, the better off will every other unit be.

Let us then lend our hearty support to any step which extends our system of vocational training, which broadens the range of educational opportunity, but, let us at the same time remember that with ever so varied a range of offerings, we are yet a long way from any reasonable social efficiency if we say to this or that class in our society, you may be educated only in this field, these other opportunities are closed to you.

Briefly, we must pay greater attention to the "sorting" of our raw material.

Harry Barker: There are two matters which have been mentioned, the one by Professor Caldwell and the other by several members. Professor Caldwell spoke of the work of vocational guidance which has been started in a number of places, and the others have mentioned the need of weeding out unfit men in college courses, and in vocational courses to a certain extent. These two things may go hand-in-hand in the elementary public schools. A start has been made to carry out such work along

psychological lines, but so far the work has largely been along economic improvements. There are ways in which you can detect abilities, tendencies, bents, etc., but only a few people in the country have any real knowledge which can be brought to bear practically on this matter. Yet a start has been made and it is well for engineers to keep in touch with this particular phase of vocational guidance. The one man in the country who can speak with greatest authority on this phase of vocational guidance is Professor Muensterberg, and he is going into the matter seemingly very deeply. He seems desirous of sharing the results of his studies and has published many details of his procedure.

The ways in which we can detect budding ability and bent or trend towards certain qualities need to be considered along with bureau work which makes vocational guidance stand for certain economic improvements. We do not want to lose sight of mental scrutiny in the great stress which is being put upon industrial opportunities.

Arthur J. Rowland: The general topic for the present report of the Educational Committee is "Industrial Education." This is also carried at the heading of each page of my part of the report. It was not my intention to limit what I had to say to that education which trains men in industry or in the industries; but rather to consider education planned to train those working in the industries for wider usefulness, and for higher places. Relatively little of what I have described has for its aim the training of routine workers; the object is rather to develop intelligent understanding of why a given routine method is used, and the principles behind it, along with an appreciation of the relation of science and technical subjects to everyday affairs. Such training fits a man for greater usefulness with the corporation for which he works in the position he holds; and also makes him available for advancement to places of higher responsibility. The interest most corporations take in the education of their employees seems to center on this last fact. A man who is worth anything, who has been tried out in a humble place where his personal qualities have become known, is preferred for advancement to a higher place, if educational limitations are not too great, above the one who comes in unknown and untried.

The scope of the paper has been limited to that education offered to men who are employed and to the subjects which have to do with industrial and technical training. In my paper I have not attempted to deal with this subject exhaustively. I have not included every school in Philadelphia and vicinity. I may not have done justice to the evening school work of the Public School System of Philadelphia. The statements made near the top of page 1427 are based on the fact that except for trade school courses the subjects offered are, almost all, those belonging to *regular* high school work. The city of Camden, N. J., just across the Delaware River, has taken hold of the prob-

lem of industrial education in a very careful way through its Superintendent of Public Education, and is now giving evening instruction in wood, metal working, and in elementary mathematics. Certain firms have been, in a limited way, undertaking instruction (of the school kind) for their employees.

At this present time I believe it is safe to say that nothing has been done in Philadelphia in the way of "continuation" school work except as noted in the last section of the Committee report in certain of the Pennsylvania Railroad shops. There is a pretty strong feeling among Philadelphia educators interested in vocational work that continuation schools may be all right in Germany; but that this kind of work to be successful must be limited to countries where class distinctions are closely drawn and the highest aim in the education of a worker is therefore to make him thoroughly skilled in his own line and sufficiently intelligent to find "joy in his work." In America every man is pushing for higher places in the shop and in the social scale; for better and fuller recognition of his best capabilities. Such a condition is fundamental in a democracy like ours and all education should take account of it.

In my paper I call attention to the fact that in Philadelphia the various schools have each developed the kinds of education they offer, and the subjects of instruction they are prepared to give, in a thoroughly individual way. This has a certain kind of merit. It also has some serious faults. Since the paper was written an effort has been made to associate all the institutions offering evening instruction in technical subjects, especially those relating to engineering, for purposes of better mutual understanding and in order to afford a means of dealing with the educational problems of our city in a direct way as a unit. The advantages of co-operation have already been felt and during the summer it is probable that much will be done to correlate properly all this work, to associate it with needs and wishes of manufacturers and corporations, to have it properly understood by the general public. It has developed that there is as much value to be gained by educational institutions who come into close association in a definite organization as there is by manufacturers and business men in their trade organizations. At the present time in Pennsylvania there is a good deal of stir about educational matters, especially in relation to those who have not had or cannot have the advantages of the standard forms of education. The organization of Philadelphia schools, etc., just referred to, is likely to become identified with a state-wide movement for educational uplift.

A tendency of our day is to establish many kinds of schools and many subjects of instruction, especially in industrial and technical lines. I believe there is danger of creating too many. The newer kinds of vocational training proceed from the concrete to the abstract; from practise to theory. This leads to all sorts of trade instruction as fundamental. The number of trades is

almost limitless and the fundamental principles connecting with them are relatively few. A little vocational guidance work would show workers and those interested in their education the need of instruction in principles, and much more than in practise. Many illustrations might be given, but I will not take time for them. Planning mainly for the teaching of principles, a few classes only for which there was large demand might be organized. A constantly increasing number of specialized classes offering new problems in teaching and new requirements in text-books would be avoided.

Corporation schools are beginning to attract considerable attention. Specialized instruction will always be required in every business and industry in order to qualify its workers to meet its individual problems well and intelligently. Such instruction the school cannot give, since each of its classes has members from among the employees of many corporations. On the other hand, the corporations cannot plan to teach principles and general subjects, which are fundamental and necessary prerequisites to intelligent specialized instruction, unless they duplicate the equipment and faculties of existing schools. Since such schools commonly require heavy endowments or state appropriations in order to operate, the expense to a corporation (if the work is well done) is prohibitory.

Many societies claim to have educational work in connection with their monthly or bimonthly meetings. This always takes the lecture form and is "smattering" in character. Its value is much over-estimated. A man doesn't know a technical subject unless he can talk on it himself and work out problems connected with it. This can be secured only by *systematic* training accompanied by recitations under a teacher.

Correspondence school work is also of small value. Unless supplemented by direct instruction, and, in many subjects, by opportunities to conduct personal experimental work, not much can be learned. The experience of most evening schools with correspondence school students who seek them proves this.

Referring now to the paper at page 1413, we find my feeling about evening school work, based on twenty years of experience in it.

In training workers for wider and higher usefulness in their chosen vocations, the education must be restricted in scope; given by an experienced teacher who can respond to the difficulties of his scholars; and must be laid out so that a worker in a humble place can be trained for a position higher up, attaining which, the training for something still further on can be secured, and on and on indefinitely. Such opportunities are being developed more and more in evening school work in Philadelphia. The same thing could be done in part time schools of a "continuation" type, and it is hoped that somehow this will be tried out in the near future.

DISCUSSION ON "AUTOMATIC SUBSTATIONS" (SUMMERHAYES), "CONVERTING SUBSTATIONS IN BASEMENTS AND SUB-BASEMENTS" (JAMIESON) AND "OPERATION OF FREQUENCY CHANGERS" (FUNK), COOPERSTOWN, NEW YORK, JUNE 26, 1913. (SEE PROCEEDINGS FOR JUNE AND JULY, 1913.)

(Subject to final revision for the Transactions.)

D. B. Rushmore: I will bring up certain points of unusual interest in the situation brought forward in Mr. Summerhayes' paper on automatic substations, because of the possible large development along this line. There is such a large field of application of electric energy, and such a large field of undeveloped sources of power now awaiting the man who can reduce the cost of operation, either of application or development, that it is an interesting subject to consider.

In a great many places there are operating conditions in which an automatic substation would allow electricity to be used where otherwise it would be uneconomical, and in the big field of agricultural operations, it would appear that there might be considerable use of such installations. There is already in existence a small substation in which the machinery is supposed to run indefinitely. Mr. Moody has put a continuous-running substation on a pole, without any attendance, and put a revolving machine there which is supposed to run indefinitely, almost without inspection. In mining work, especially, and in work subject to labor disturbances, the advantages of automatic substations are very evident, and it is very interesting to look forward and see the possible growth of this work.

F. D. Newbury: Mr. Summerhayes' paper is an interesting solution of a very difficult problem. I would like to hear, though, from some of the operating men, as to their feeling in connection with the operation of fairly large machines without superintendence at all times. There has been, of course, a large amount of remote-control machinery installed, but it has been, in general, in relatively small capacities and of course, in practically all cases the machinery has been of the non-commutating type. Remote control is certainly in the direction of economy, and it will undoubtedly continue to develop. It is, moreover, directly in line with the extensive use of outdoor transformer and oil switch substations, which two or three years ago were looked upon with a good deal of skepticism, if not disfavor.

There are two minor points in the paper I would like to refer to. The possibilities of the converter coming up with the wrong polarity is nicely taken care of in this case by separately exciting the converter. Separate excitation, however, will not be generally available. This is particularly true of railway substations that do not have a storage battery or other direct-current source of supply.

The two-thirds voltage switch also is mentioned, but I do not believe that that additional application is necessary—certainly not in the 500-kv-a. converter—and the switching could be

considerably simplified by using only one starting voltage instead of the two.

In Mr. Jamieson's paper, I wish to emphasize from the designer's standpoint the necessity for an adequate supply of cool, clean air. As Mr. Jamieson well points out, it is difficult to obtain, but it is absolutely necessary to the life of the machines if they are to be operated at a rate that is at all economical. With substation air temperatures of 40 deg. or 45 deg. very little is left between that and a permissible 90 deg. for temperature rise in the apparatus.

In connection with the cleaning of the air, Mr. Jamieson mentions an ingenious vacuum air filter. Several air washing outfits have been developed and have been used to a limited extent in this country and quite extensively abroad. That, I should think, would be particularly adapted to the restricted space of substations in basements, and I would like to know if it has been applied to that work.

In connection with Mr. Funk's paper, while it is somewhat outside the range of his paper, I would ask if he has had any experience with the use of pumps in order to introduce oil pressure under the bearings before starting, in order to facilitate starting. That has been considered, and I know such a system has been installed. If he has had any experience with such an outfit I would be glad to know the results.

F. C. Caldwell: In connection with the paper on automatic substations, I would call attention to the fact that an automatic resetting circuit-breaker is now being developed and will shortly be on the market. This breaker, of course, opens when there is an overload and then will not close again until the overload goes off of the direct-current circuit. As soon as this happens the breaker closes and is again ready for operation.

Paul M. Lincoln: I am reminded by Mr. Summerhayes' paper of the old saying that the proof of the pudding is in the eating, and not in the chewing of the strings of the pudding-bag. I consider that our getting up here and talking about this matter of distant operating substations is considerably in the nature of the chewing of the strings of the pudding-bag. The crux of the matter lies in how it operates, and whether it gives satisfaction to the operators, and whether it is cheap. We are told by Mr. Summerhayes it has been in operation for some time and gives promise of being a solution of the problem of substations operated without attendance. I trust so, and I believe that Mr. Summerhayes is to be congratulated on working out the details of the automatic substations so completely.

H. M. Hobart: As to Mr. Newbury's suggestion about washing the air, it may be interesting to mention that the London Electric Supply Station at Deptford has several large turbo-generators, of 5000 kw. each, which supply the London, Brighton & South Coast Railway with power, and the air is being washed by being passed through sprays of water. This is the largest

installation of this character, I believe. Water filters are also used for washing the air supplied to the turbo-generators of the Brighton Electricity Supply Corporation. The system performs the additional function of cooling the air, as well as washing it. If the air is cleaned by filtering it through cloth screens the screens gradually become clogged up, and the machines will get very hot, until the screens are cleaned, whereas by passing the air through water sprays nothing can get out of order.

Henry W. Peck: Mr. Summerhayes' paper was very interesting to me, as I have had some operating experiences along the lines dealt with in the paper.

Regarding Mr. Newbury's suggestion, I would have little hesitation in applying such a system in certain cases. In the stations the trouble comes so quickly that even if you have an operator you are relying on the automatic regulation to protect the station and the system. If the automatic equipment does not work, your main station, or the equipment of it, is apt to be seriously damaged even if you have attendants there.

I would like very much to have Mr. Summerhayes work out this idea along the line of our discussion yesterday regarding synchronous condensers. It might be somewhat more difficult than the station which he describes in his paper, but I am not sure that it would be. You would then obviate the difficulty suggested yesterday of having inefficient operators with whom to trust the operation of the synchronous condensers. Thinking it over very briefly, I can see no difficulty in arranging automatic devices to get the desired effect of field strengthening or weakening to vary with the conditions. It seems to be no more difficult than some things which our designing engineers have accomplished. The economy of such an automatic station is especially great in view of the feeling on the part of operating men that more than one man must be present in any building which contains high-tension or even moderate tension electrical apparatus. The presence of two men in the station is required in some states by law, or city ordinance. Many companies feel it is not safe, even though there is no law requiring it, to have less than two in the station: This means that even in a small station, where there is not enough to keep one man busy one-quarter of his time, we must have two men present at all times. The economy, therefore, of a station without attendants is exceedingly great.

S. D. Sprong (by letter): This paper presents a rather novel adaptation of standard apparatus as a commercial expedient. The plans as shown reveal a very careful working out of the elements of the problem and an excellent judgment in the selection of the automatic devices to meet the unusual condition of absence of manual operation and immediate supervision.

It is, however, this very complete provision for remote control and automatic means to prevent damage to the apparatus that emphasizes the point which the author seems to consider of

paramount importance. I refer to the fact that there is apparently no special thought or provision to safeguard the service even though at the possible expense of the equipment. Continuity of service, especially in an underground district of this character, should have first consideration under all conditions and it is a frequently emphasized rule among most light and power companies to maintain service even when it may probably result in damage to apparatus or equipment. The author appears to take quite the contrary view in that all the automatic and other provisions for meeting emergencies are designed to safeguard the apparatus, which exaggerates much beyond its true relative value the safety of the equipment as compared with the maintenance of service. I believe that any section of the city that would justify the installation of an underground d-c. system, is of such importance as to justify the relatively small additional expense of substation operators, the wages of which when capitalized would secure more of the elements that go to the maintenance of satisfactory service and the meeting of emergency conditions than any elaboration or duplication of automatic safety devices and methods of remote control.

I would suggest as an alternative, the employment of a substation operator covering a ten-hour period from 4 p.m. to 12 midnight, which would cover the heavy load period, and during the remaining fourteen hours and Sundays the lighter load could be carried by trunk feeders from one of the regular substations and controlled by pressure wires. Assuming the low load factor of 25 per cent this would give about 1,000,000 kw-hr. output per year. With a labor cost for the single operator of about $800 it would show about eight hundreths of a cent per kw-hr. additional cost on the whole consumption in this district. As the character of the load in this district is almost entirely retail and therefore at the maximum rate, an additional output cost of eight tenths of a cent would be more than offset by the numerous advantages to be obtained in such a district by having an operator in charge during important hours of the load.

H. R. Summerhayes: Mr. Newbury referred to the possibility of operating large machines without attendance. I think that large machines are possibly more reliable than small ones. It is only on account of the larger investment involved that people would hesitate to extend this principle to very large machines. Where the investment is so large that you can afford to have an operator on account of certain hazards, such as the fire hazard, for instance, the advantage of this form of automatic operation is not so great as in cases where the attendant is not required on account of the fire risk. So far as the operation of a machine is concerned, I should think the larger machine is fully as reliable as the smaller one.

In reference to the matter of polarity, also brought up by Mr. Newbury, Mr. J. B. Taylor devised several years ago a polarized relay to be connected across the commutator, across the brushes,

and as the machine goes up to synchronism, that relay would be getting alternating current. As it came very near synchronism, it would be polarized current, and the relay would be prevented by a dashpot, from going to its full travel. It would not operate finally, until synchronism had been obtained, when direct current would be supplied to it, and then it would operate in a direction determined by the polarization of the relay.

J. C. Lincoln: Suppose it happens to get in synchronism, so the relay was kept out, what is there to make the relay slip forward?

H. R. Summerhayes: It will be arranged to reverse the connections so that it is connected to the bus in the right direction.

Mr. Newbury brought up the point of the two-thirds voltage switch. When we first laid out this remote power plant, we started on one voltage, and threw on all the voltage, but it was thought desirable to put in an extra switch, because we were not sure at first exactly what field strength would have to be used, and as a matter of fact, we can go through from one-third voltage to full voltage without creating any disturbance, but in order to do so we must first make the full field, which can be done, but the field on this machine is so strong that there is somewhat more disturbance in throwing over with a strong field than by the method used.

Mr. Peck referred to the operation of synchronous condensers automatically, that is, automatically restarted, I suppose. Ithink a synchronous condenser can be arranged so as to be operated by an automatic voltage regulator, and operated practically without attention. Either that, or a synchronous motor can be arranged so that if the power goes off the transmission line, and then comes back again, the motor can be restarted. I know of a case now where it is planned to put in a restarter for a synchronous motor. In this case a town is lighted by a frequency changer, a 60-cycle line, the synchronous motor driving this set being supplied from a 25-cycle transmission line. The apparatus is modern and the operator does not spend much time in the station, but is able to give a large part of his time to other duties. Everything operates all right except when the power goes off the line, and then the frequency changer shuts down and the operator must go back and start up. I proposed an equipment for that station so arranged that when the motor falls out of step it will be thrown on the starting taps, so that when the power comes back it will be automatically restarted, and the proper arrangements for field and load will be taken care of automatically.

Mr. Lincoln asked if the operation is satisfactory. I do not know whether there are any of the Detroit Edison people here, but Mr. Cato intended to be here. I recently talked with Mr. Cato and he said he has not heard from the station for a long time, that they send a man there once a day to inspect it, and he has not heard any complaint regarding the station, and that it operates satisfactorily.

As to the heating of the building, this substation in Detroit is not heated, and that expense is saved as well as the expense of the operator.

D. W. Roper: The only question raised, I believe, was as to the cleaning of the air supply, suggesting that this be done by washing rather than by screening. In the substations covered by Mr. Jamieson's paper, the limitation, I believe, has been generally found to be one of space, for the washing scheme requires more space than the air screening system. The washing system has been tried in one or two of the smaller installations, and the reason for its lack of success was because there was not sufficient space for a proper installation. However, if a screen device with a vacuum cleaner can be worked out, it would appear to be simple and require less attention than the washing scheme.

N. E. Funk: Concerning the oil pressure supply to the bearings to make the machine start easily, in the case of the two machines I have in mind, one 3000 kw. and one 6000 kw., it was not necessary to use oil pressure in the bearings of the small machine as it started easily. It was impossible to start the 6000-kw. machine with a 300-h.p. motor consuming about 600 h.p. unless an oil pressure of 150 lb. per sq. in. was applied for about 3 min., and then it started very slowly. If oil pressure was applied for about 5 min. a crack was heard in the bearings indicating that the shaft had lifted from the bottom of the bearing, and the machine started easily.

Discussion on "A Suggestion for the Engineering Profession" (McClellan), Cooperstown, New York, June 24, 1913. (See Proceedings for June, 1913).

(Subject to final revision for the Transactions.)

C. O. Mailloux: Mr. Chairman and gentlemen, I regard this paper as one of the most interesting papers that has been presented to the Institute for some time. The President has said that this is *the method* of raising the social status of engineers. I look upon it as *a* method, because I think there are many methods. I have looked forward for many years to greater coöperation among engineers. It has been one of my hobbies. There has been a tendency among engineers to segregation; the different bodies have tended to undergo a process of evolution in different directions, in many respects, in regard to their points of view, and their attitude towards public questions, and also even in regard to their ethics and their methods of professional discipline and conduct. Many engineers in the different branches of engineering realize this, and they also realize the importance of doing something to improve conditions; and various remedies to overcome the conditions that now exist have been proposed.

The American Institute of Consulting Engineers, which has recently come into some prominence, has attempted to bring together the different branches of the engineering profession into a body that will work for the profession of engineering in general. That body is interested more specifically in the welfare of consulting engineers, which is well enough, as far as it goes, but is, perhaps, not as good as it might be if it were sufficiently comprehensive to include engineers of all types, for there are many prominent and eminent engineers who are not consulting engineers, and can not be properly classed as such. I think the suggestion of Dr. McClellan is a very good one indeed. In the way he has formulated it, it is very excellent, but I am not so severe as he is inclined to be as to the means of carrying it out. I think the matter should be carried out by the Institute. It has been the pioneer of progress in the development of many good ideas in this branch of engineering, and in other branches of engineering, generally.

We have inaugurated the Section movement, which is being taken up by other branches of the engineering profession, and I do not see why this body should not be the fostering spirit of a movement of this kind, looking to coöperation among the different branches of the engineering profession.

I would like to make a motion that this matter be referred to the Board of Directors, as I consider it well worth the closest attention of the Board of Directors; and it should serve as the basis of a thorough study and investigation of the question, the Board of Directors to be given full power in the matter, and to indicate to the membership its conclusions in due course.

Oberlin Smith: As a long-time member of all four of the big engineering societies, I feel that perhaps I can speak on

this subject impartially, although I happen to be more closely related with the mechanical engineering branch than any other.

For many years past progressive engineers have hoped for a united engineering society of some kind. The movement was brought up some time ago, before the Engineering Societies Building in New York City was constructed, and the plan freely discussed, but with some of the societies there was too much of a clannish spirit to permit full and complete coöperation; hence nothing practical was done at that time. When, however, Mr. Carnegie gave us the building on 39th Street, many of us hoped that all four societies would come in. The fact that one of the societies remained out was a great disappointment, but I know that many members of the American Society of Civil Engineers much regret the separation. Last week at a convention of the Society in Ottawa,this feeling was brought out strongly and there was some manifestation of the spirit which has been shown in this splendid paper of Dr. McClellan's. The new president, Prof. Swain, of Harvard, gave us a most effective and interesting address. There were some things in it which seemed to be too conservative, yet he took a broad view of the subject, and regret was expressed that the various societies had not all gotten together before. At the meeting, however, there was in evidence some of the old idea that civil engineers were most important, because they covered all the ground outside of military engineering.

It seems to me that we all might get nearer together by mixing, so to speak, the councils of the different societies. Some members of the Mechanical Engineers who are also members of the Electrical Engineers should be in the Council of the Electricals, and vice versa; and this system of mixing of interests would certainly tend towards greater unity and efficiency.

Thus in the Council of each Society, there would be a few of the best-known and most fit members of each of the other societies.

There have, so far, been but few electrical, mechanical, or mining engineers represented on the Council of the American Society of Civil Engineers. I do not remember whether there are any now. Under such conditions a society can hardly claim to be at the head of all engineering activities.

I think, however, that the feeling is growing all the time, among the members of the various societies, that there should be a greater coming together, but they are not limited to the four old organizations above mentioned.

We have among them an important society, the Naval Architects and Marine Engineers; and we have numerous smaller societies, like the Society for Testing Materials, the Society for Engineering Education, the Illuminating Engineering Society, and similar organizations. We are one family subdivided into smaller branches. Of course, there are all kinds of specialties in engineering, just as there are in other professions. Spec-

ialization is increasing all the time, and must be expected. No one man can acquire thoroughly all engineering knowledge. If he knows his own specialty well, and knows about other things in only a general way, he will be likely to make a successful engineer.

I thoroughly agree with Dr. McClellan's idea that we should make some beginning and start in to organize a United Engineering Society. It would probably be impracticable to make the membership of individuals, but it could be made up of other organizations, as suggested. There is no reason why it should not be a unit by itself and have its complete individual organization, with its own separate meetings. Not only could such a society handle the matter of ethics, which has been so well taken care of by this society, but it could make suggestions for better laws and better government in all sorts of ways; and it would have a broad influence, scientific, economic, moral and social, which engineers do not now possess. We could exert our influence in a powerful way by united strength, rather than individually, as we now do. I look forward to such a movement being a wonderful success.

Chas. L. Clarke: Dr. McClellan seems to be in doubt as to whether the time is ripe for an organization of this sort. Undoubtedly the time is here, and we ought to see such an organization founded before long. The danger that it might interfere with the so-called clannishness of the member societies, is hardly possible, because the plan does not propose interference in any way with the technical business or other individual matters of such societies, but only contemplates fostering national and broad policies affecting the body politic in general, as far as engineers can help to do so, as men of education and of technical judgment.

Dr. McClellan has invited suggestions on two points. The speaker has one suggestion to make with reference to the name of the society. According to the suggestion in the paper of Dr. McClellan, it is to be called the American Engineering Association. The speaker proposes that it be called the American Association of National Engineering Societies, which title seems to explain as briefly as possible what the Association is in fact, and is calculated favorably to attract attention of Congressmen when receiving a communication relative to pending legislation sent to them by this proposed Association, for they will see just what it stands for and comprehend the situation from its name, especially if coupled with a list of its members.

D. B. Rushmore: We received a great deal of inspiration from the Address of the President this morning, and we have also been greatly impressed by the suggestions made by Mr. McClellan in his paper, and these things together lead me to believe that there is very great necessity now for some one to take these ideas and reduce them to general principles, so that the best results from coöperative effort may be secured therefrom. However, I am afraid that we are getting into a

condition of over-organization all over the country. If we take our political life, our industrial life, our social life, and our professional life, we will find that we belong to a great many more organizations than we can take an active part in.

Here we have a very interesting proposition brought forth, and the question arises: What is its practical value? Can we express in general terms this particular hope we wish to accomplish? To a person who has had to work in a large organization, and possibly not especially fitted to adapt himself to others, it has been necessary many times to think— Why an individual? Why a department? Why an organization? And what is it trying to do? All over the country you see rising up industrial organizations, political organizations, and agricultural organizations. In the agricultural organizations an interesting development is taking place. In these organizations a differentiation is being made between those things most efficiently done by individuals and those best accomplished by coöperative effort. They are being organized from beneath upward, the individual action extending as far as efficient results justify it, and further on coöperative effort is substituted, with the most beneficial results for all concerned.

In our field of engineering activities we have a large number of small societies, all actively engaged in fields of special effort. A similar result could be accomplished by joining all of these in one large holding company, and instead of separate entities, having them as members of one large whole. It is, however, a question and a serious one, as to which method of organization will produce the better results.

It is absolutely essential for the future welfare of the engineer that he should not allow himself to be pushed into the field of an exclusively pure scientist, but that he demand that his work include the consideration of money expenditures, which factor is one of the basic principles of engineering practise.

The standing of the engineering organizations and their value to their membership will depend upon the part which these organizations play in the field of industrial, social and political activity. It is most important that an unrelenting fight be waged against the licensing of engineers by the State, and the insistence that the membership rank of the engineering societies be accepted as the means by which the standing of an engineer in his own profession shall be judged. This means that considerable revision must be made of the grades of membership and the requirements for admission to such society.

Mr. McClellan's suggestion has much of value and is of interest to all engineering societies. It is worthy of much consideration, but it is suggested that it receive the benefit of all possible criticism before we organize another society.

C. L. deMuralt: I am very much pleased with Mr. McClellan's paper, and heartily endorse what Mr. Mailloux has hinted at, namely, that it is just about the right time to have this sug-

gestion made. Mr. McClellan has put it in very good form, even down to the details.

If I say anything at all, it is because I desire to make an additional suggestion: Why is it necessary to add to the many existing societies a new one? Why cannot we use one which is already in existence?

The American Society of Civil Engineers is unfortunate in that its name, according to present usage, seems to cover one branch of the engineering profession only. That is not so. Many of us are members of the Americal Society of Civil Engineers, and the American Society of Civil Engineers has always taken the view that it is the old mother society which represents all engineers in this country. Why should we not approach the American Society of Civil Engineers through our Directors, perhaps in coöperation with the American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers, the Institite of Mining Engineers, and similar bodies, and discuss with them this proposition which Mr. McClellan has made.

I am not authorized to speak for the American Society of Civil Engineers, but many of the members of that Society have told me they would like to have the support of the individual engineering societies. I have no doubt they would listen to any reasonable suggestion of having the individual societies come in with them on some broad basis. This could either be done as Mr. McClellan's paper suggests, through a lump sum payment from each society or else by allowing the individual members, if they want to join the American Society of Civil Engineers, to obtain membership by paying some agreed-upon additional fee. I think that along these lines something of real practical value could be accomplished in the direction of Mr. McClellan's suggestion.

C. O. Mailloux: I want to say a word on this question of the role or function which the American Society of Civil Engineers might have played. The American Society of Civil Engineers had the opportunity to lead all the engineering societies of this country, but lost that opportunity thirty or forty years ago, and it is too late to go back to it. The suggestion which Mr. de Muralt made would meet with enormous opposition in the minds of a few fossilized civil engineers who believe in the lion and the lamb lying down together, provided the lamb is inside of the lion. When the lion has become a small thing, dwarfed, in comparison with the lamb, the suggestion is preposterous. I am second to none in my respect for ideals in engineering, and I think I have done my share in the work of raising the ideals of engineering. I know we cannot accomplish the objects which Dr. McClellan seeks to accomplish by proceeding along that line, for the reason that the very things he seeks to have done, namely, the pursuit of ideals, the participation of the engineering profession in the consideration and determination of public

questions, are notoriously the very things which the American Society of Civil Engineers has always dodged and kept away from, and on which it has been afraid to hold distinct and pronounced opinions.

C. L. de Muralt: That, of course, is an individual opinion. It may be shared by many here, but I do not quite see why my proposition is necessarily ridiculous and preposterous. The American Society of Civil Engineers might have had some fossilized members thirty or forty years ago—I was not an engineer at that time—but it does not seem to me fair to cast reflections upon the present membership of that Society on the basis of what happened thirty or forty years ago. I know, as a positive fact, that those who are now managing that Society are not fossilized and I have reason to believe that they are very much in favor of such a movement. They should be approached to find out if it is not possible to carry out Mr. McClellan's idea, without starting a new and unnecessary society.

Oberlin Smith: The American Society of Civil Engineers was, I think, the first engineering society of consequence established in this country. I have great respect for it as a body, but it constitutes only one branch of the profession. Applied to their branch only, the term "Civil Engineers" is a misnomer, and does not mean anything because most of the rest of us are also "civil". The term was of course used in contradistinction to the term "military engineers," and was applied to all engineers other than those engaged in military work. Although not logical as at present used it probably will remain with us, but it cannot be a comprehensive name for a united society. If we have a new society, we should not call it "The American League of National Engineering Societies." We rarely could spend the time to pronounce the whole name, but would call it by its initials. Witness the sad case of the American Society for the Prevention of Cruelty to Animals; we always call that the A. S. P. C. A. and then have to think it out. There is a great advantage in having a short name for a society or other organization so that people will be able quickly to remember what the initials stand for. We should have "American Engineering League," or some such name, the shortest that we can get. If a Congressman or such should not know what A. E. L. stood for, we could have the full name presented for his notice, far better than we could a very lengthy one.

D. C. Jackson: This paper has much of suggestiveness in it, and it proposes one of those things which ought to be put into execution. It is one of those things which has been discussed year after year for a long period of time. I hope that Mr. McClellan's entry into the lists will result in the accomplishment of the purpose. I am with him thoroughly, but I want to criticize his paper in a small way.

We generally recognize, I think, that the old definition that comes down from Tredgold, that "Engineering is the directing of

the forces of nature to the use and convenience of man," is a correct definition and sufficiently ample and comprehensive of all modern engineering practises of today. If it is a correct definition of engineering, then what are engineers? I have put the definition of engineers as "Those who are competent to conceive, devise and organize the directing of the forces of nature to the use and convenience of man." If that definition is correct, then it is not quite fair to our profession to eliminate therefrom (as Mr. McClellan's classification purports to do) some of the men who are working distinctly on the scientific aspects of engineering and doing little towards direction and execution. We must include within the profession those men who are scientists primarily, and engineers secondarily, or vice versa. We must also to some degree go over to the other side and include some men who are executives and administrators of engineering enterprises, and also men of engineering ideals and views although their active work may be done in the laboratory or school; in other words, we must make our definitions and our ideals of the profession as comprehensive as may be necessary to take in all these men. This is scarcely a criticism of Mr. McClellan's admirable paper, but a suggestion of the way in which his proposed classification should be modified.

DISCUSSION ON "TEST OF AN ARTIFICIAL AERIAL TELEPHONE LINE AT A FREQUENCY OF 750 CYCLES PER SECOND" (KENNELLY AND LIEBERKNECHT) AND "THE ADAPTATION OF AUTOMATIC METHODS TO LONG DISTANCE TELEPHONE TOLL SWITCHING" (FRIENDLY AND BURNS), COOPERSTOWN, NEW YORK, JUNE 24, 1913. (SEE PROCEEDINGS FOR JUNE, 1913.)

(Subject to final revision for the Transactions.)

F. K. Vreeland: In view of what Mr. Colpitts has just said about the values of tables III, IV and V being computed, not from the actual constants of the line given in Tables I and II, but from empirical constants derived by experiments with the line as a whole, and worked back from Table VIII; I would ask whether he can give us any information as to the agreement of these empirical constants with the actual measured constants of the line?

E. H. Colpitts: The authors give the line constants in the paper. I did not call particular attention to these tables because in the discussion of his results, Prof. Kennelly has not used the electrical constants of the artificial line at 760 periods per sec., in other words, Tables I and II are merely descriptive of the apparatus that he used.

Answering specifically Dr. Vreeland's question, I would say if you assume the "accepted mean values" of Prof. Kennelly, in Table VIII, that is, a surge impedance of $465 \backslash \overline{11}^{\circ}$ ohms, and a mean section angle of $(0.235 + j\,1.272.)$ are correct, the line must have the following electrical constants at 760 periods per sec.

Effective resistance................119 ohms;
Effective inductance................ 0.0926 henrys;
Effective capacitance.............. 0.670 mf.
Effective leakance.................164 micromhos.

D. C. Jackson: While this desirable and interesting paper relates to a test of an artificial aerial telephone line using currents having a frequency of 760 cycles per second, it is nevertheless, a paper of just as great interest and significance to the man who is working in power transmission in large bulk as to the man who is working in power transmission in very small bulk; that is, what we call heavy power transmission, on the one hand, and telephone transmission on the other. Of course, when we are working on power transmission in large bulk we are endeavoring to transmit a fundamental frequency, and to eliminate the harmonics. In the case of the telephone, on the other hand, the necessity is to transmit all the harmonics preserved in substantially equal degree over a large range of frequencies.

The significance of this paper, then, is great to both power transmission men and telephone men. One of the important papers that have come before the Institute in relatively recent years is the description of an artificial line which Dr. Kennelly published, I think, a year or two ago in the Institute PROCEEDINGS.

As I understand it, the present paper embodies the results of tests on that same transmission line, and it contains another demonstration that the formulas including the hyperbolic trigonometrical functions are highly accurate for the computation of transmission lines. That has been very well proved previously by actual telephone circuits.

As far as heavy transmission service is concerned, the frequencies are so low and the lines so relatively short that practise has not yet gone far enough to meet a quarter wave length or half wave length in actual practise, but we are surely coming to it, and it is essential that these formulas shall be studied by transmission engineers.

F. K. Vreeland: It is exceedingly interesting to me to note the close agreement between Prof. Kennelly's experimental results and the computed values, though it would be still more interesting if the computed magnitudes were computed from the beginning instead of being worked back from tests on the completed line. As everybody knows who has had occasion to work with questions of line propagation, the artificial line is a very valuable experimental adjunct, but I think, perhaps, we have all felt some doubt as to how closely the predicted results of the artificial line agree with those we get in real practice. Prof. Kennelly's tables and diagrams of computed and observed magnitudes show the degree of divergence of the "lumpy" artificial line from an equivalent uniform line, but they do not show to what extent the performance of an artificial line may be predicted from predetermined line constants. Mr. Colpitts has, however, thrown some light on this feature. I notice from the figures Mr. Colpitts has given us that there is a close agreement between the empirical constants of the line which are computed back from Prof. Kennelly's experimental results and the actual values given in Table II, except in one very important respect, namely, the apparent resistance. Mr. Colpitts gave the apparent resistance per section computed back from Table VIII as 119 ohms, whereas Prof. Kennelly gives the measured value at 760 cycles, as 33 ohms. Prof. Kennelly points out a large discrepancy between this 33 ohms at 760 cycles and the measured apparent resistance of 125 ohms at 60 cycles, which is closer to the empirical value, 119 ohms, obtained by calculating back than it is to the measured value of 33 ohms at 760 cycles. This discrepancy is surprisingly large. Can Mr. Colpitts tell how Prof. Kennelly's measurements were derived? Is the capacity the true Maxwellian capacity, that is represented by a 90 degree leading current component, and is the inductance represented by a similar lagging component and the resistance by a pure energy component, or do those constants represent some of the multitudinous methods of measuring capacity, inductance and apparent resistance which do not give the true or Maxwellian values?

E. H. Colpitts: Unfortunately, I can not authoritatively answer Dr. Vreeland's question, because I have not discussed

the point with Prof. Kennelly. I would say, however, that the computations which we have made in order to determine what values of line constants would give the values of surge impedance and propagation constant which Prof. Kennelly found for the line, determined the effective constants at the frequency in question. In the case of the effective resistance, for instance, the value found may correspond to losses in the copper conductor alone or it would correspond to such losses plus losses in an iron core if an iron cored coil had been used. In the same way the capacity and conductance correspond to an ideal condenser, having the value of capacity which I quoted, and shunted by an idea resistance giving a conductance equivalent to the figure quoted.

George A. Campbell (by letter): The paper refers to the fundamental steady state constants of a line as its "surge impedance" and its "hyperbolic angle." Our practice is to call these constants the "iterative impedance" and the "propagation constant" and these terms seem to me preferable because the first is more exact and the other is more fundamental. It is a matter of some importance that the best terminology should be standardized as these constants occur in almost all discussions of lines, whether uniform, loaded or artificial.

The constant referred to as the "surge impedance" applies to a steady state condition of the line and has no necessary connection with the behavior of the line towards a sudden rush of current. In general, the ratio of the electromotive force to the current is not a constant for an impulse or any other unsteady state, so that the conception of an impedance which has proven so useful in connection with steady state phenomena does not apply to transient phenomena. Heaviside's distortionless circuit is a striking exception for with that the current which starts out on the line is always an exact copy of the applied electromotive force. If a distortionless circuit were loaded (with the first load not at the sending end) it would have a true surge impedance which would be the surge impedance of the distorionless circuit taken alone, but its so called "surge impedance" as that term is used in the paper would be something quite different. As this use of "surge impedance" is a misnomer, it is desirable to adopt a more exact term if it is not quite as short or familiar.

The term "iterative impedance" is advocated for this constant because the distinguishing feature of the impedance is that it repeats itself if the line is closed through this impedance at the far end. The synonyms such as repeating, periodic, cyclic were not considered desirable because these terms are in wide use in connection with telephone theory. In mathematics the term is already employed in this same way, the dictionary definitions being:

iterative function: "a function which is the result of successive operations with the same operator." (Century).

"a function resulting from successive operations with the same operator." (Murray).

As applied to a line the "operator" is the transformation due to a section of the line; if the line is uniform the section may be chosen of any length; if the line is of periodic recurrent structure such as a loaded line or an ordinary artificial line, the minimum section is a periodic interval. The definition which we have adopted is:

Iterative impedance: "the iterative impedance of a line of periodic recurrent structure at a specified point, for propagation in the specified direction, is equal to the limit approached as the line is made infinite in length, by the driving-point impedance of the line beginning at the specified point extending in the specified direction, and terminating in any physically possible impedance."

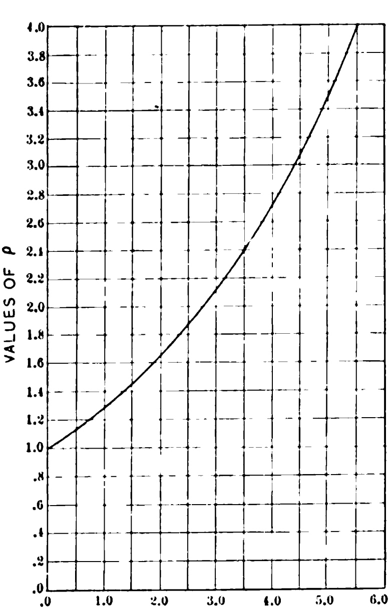

FIG. 1—AMPLITUDE CURVES FOR $e^{x\,(a+i)} = \rho \text{ cis } \theta$

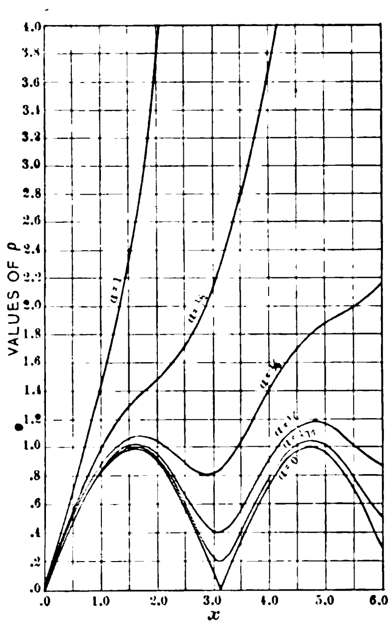

FIG. 2—AMPLITUDE CURVES FOR $\sinh x\,(a+i) = \rho \text{ cis } \theta$

This definition covers uniform lines, loaded lines and artificial lines, which may or may not be symmetrical in the two directions, and it has been made to exclude the theoretical iterative impedance having a negative resistance component by the restriction to any physically possible impedance at the far end of the line.

(Mathematically there are always two iterative impedances for each direction of transmission, one of which has a negative resistance component; the impedances for either direction are equal to the impedances for the other direction with sign reversed.)

"Propagation constant" seems to me to be preferable to "hyperbolic angle" because our basic conception of steady state cisoidal transmission over any periodical recurrent line is that it is compounded of a direct and a reflected wave, each of which falls off exponentially from one periodic interval to the next; we never picture the wave as being divided physically into a hyperbolic sine wave and a hyperbolic cosine wave. In the wave which falls off exponentially the amplitude decreases in geometrical progression from section to section, while the phase lag increases in arithmetical progression. This is so simple that it is very easily grasped. On the other hand, the

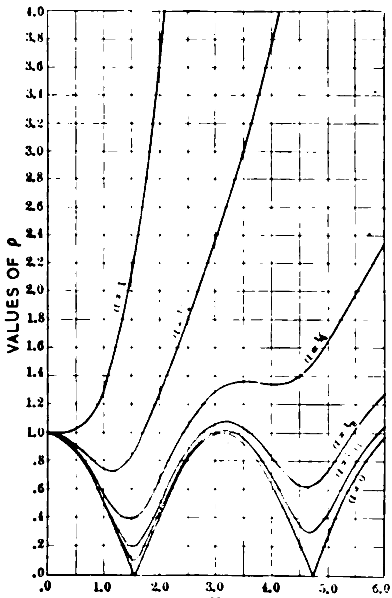

FIG. 3—AMPLITUDE CURVES FOR $\cosh x\,(a+i) = \rho \text{ cis } \theta$

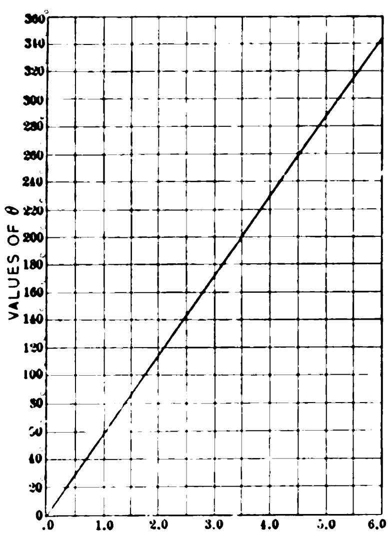

FIG. 4—PHASE ANGLE CURVES FOR $e^{x\,(a+i)} = \rho \text{ cis } \theta$

amplitude and phase relations in a hyperbolic sine or cosine wave are so complicated as to be grasped only with difficulty. The usefulness of hyperbolic functions of complex quantities in transmission theory is mainly confined to analytical work and it is a matter of comparative indifference whether hyperbolic functions or circular functions of complex quantities are employed, since any expression in one form may be read in the other form without rewriting, and upon clearing the formula of imaginary quantities hyperbolic functions and circular functions occur in equal numbers.

As hyperbolic functions are analytical means rather than

expressions corresponding to any fundamental physical phenomena it does not seem advisable to introduce them into the fundamental terminology, while it does seem advisable to retain for the complex quantity which shows how the fundamental exponential wave varies in amplitude and phase the term "propagation constant."

Curves of amplitude and phase angle are shown by the accompanying drawings for cables ($a=1$) and ideal open wire lines ($a=0$) and also for intermediate values of the attenuation constant per wave length. For the exponential function two simple curves suffice for all cases by a mere change in the scales

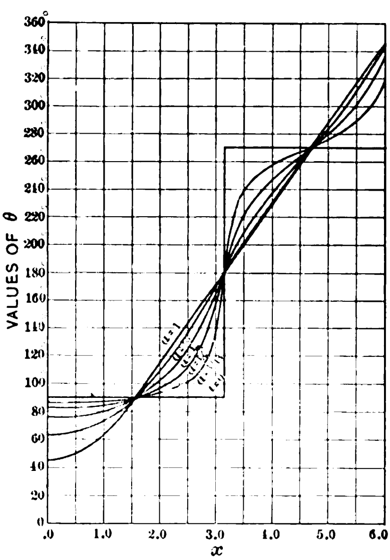

FIG. 5—PHASE ANGLE CURVES FOR
sinh $x\,(a+i) = \rho$ cis θ

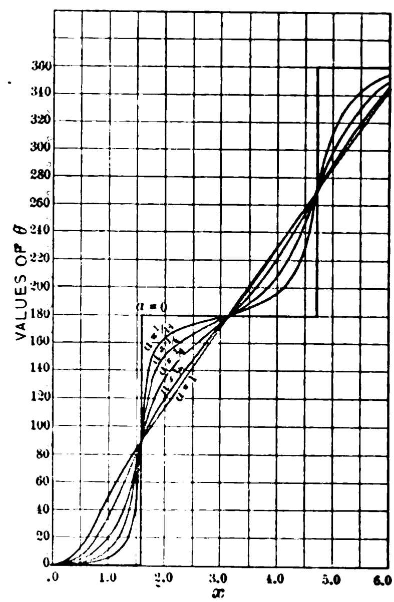

FIG. 6—PHASE ANGLE CURVES FOR
cosh $x\,(a+i) = \rho$ cis θ

employed. To picture the hyperbolic function in the same way requires four families of curves which are comparatively complex, the individual curves becoming more and more wavy with decreasing attenuation per wave length.

R. S. Brown: In connection with the curves of current and voltage variation shown in Dr. Kennelly's very interesting paper the author would like to describe a method he has devised for plotting such curves by graphical integration. The method applies equally well to current and voltage on transmission lines and inasmuch as all the integration is done graphically it is unnecessary to deal with exponential functions. It is

not proposed as a method for solving all transmission line problems, as here length of line is usually a constant and the conditions at some definite point are sought. Such problems are solved more directly by the use of tables of hyperbolic functions, for long lines, and approximations for short lines. This method will prove useful however for the solution of lines at high frequency, such as telephone lines, which are not covered by the ordinary tables, and in all cases where it is desired to investigate conditions at progressive points along the line as in the calculation of corona loss on power lines by the quadratic law.

The well know differential equations for voltage and current on a line with uniformly distributed constants are;

$$\frac{dE}{dl} = Z\,I \qquad (1)$$

$$\frac{dI}{dl} = Y\,E \qquad (2)$$

Dividing,

$$\frac{dE}{dI} = \frac{Z}{Y}\frac{I}{E}$$

The integration of this equation gives

$$Y\int_{E_0}^{E} E\;dE = Z\int_{I_0}^{I} I\,d\,I$$

$$Y\,(E^2 - E_0^2) = Z\,(I^2 - I_0^2)$$

or, if $\sqrt{\frac{Z}{Y}}$ is the surge impedance of the line, which we will call s,

$$E^2 - S^2\,I^2 = E_0^2 - S^2\,I_0^2$$

Let

$$F = \sqrt{E_0^2 - S^2\,I^2} \qquad (3)$$

The quantity F, then, is the same for every point on the line if the line be free from taps.

Solving for I,

$$I = \frac{1}{S}\sqrt{E^2 - F^2}$$

But.

$$\frac{Z}{S} = \sqrt{Z\,Y} = \theta$$

Where θ is the hyperbolic angle subtended by the line in vector radians per mile.

$$\frac{dE}{dl} = \theta \sqrt{E^2 - F^2} \tag{4}$$

Hence,

$$\frac{dE}{\theta\, dl} = \sqrt{(E + F)(E - F)}$$

Since l is a real number it is seen that the angle of $\dfrac{dE}{\theta}$ is one half the angle of $(E + F)$ plus one half the angle of $(E - F)$. This angle may be found by bisecting the angle at the vertex

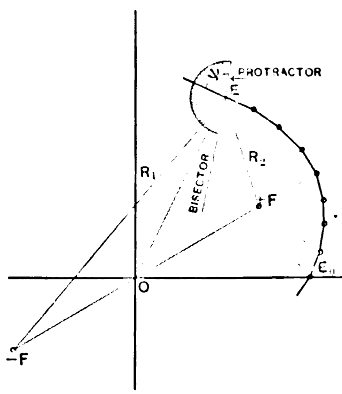

Fig. 1

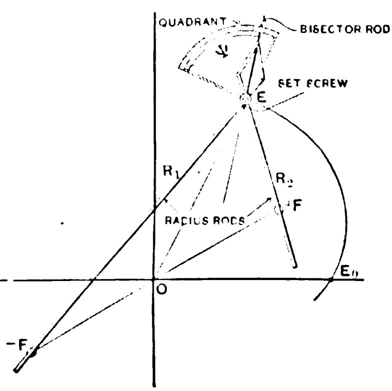

Fig. 2—Plan View of Integraph.

of the triangle formed with $\pm F$ as base and $(E - F)$ and $(E + F)$ as sides. The angle of dE will then be the angle of θ in advance of the bisector, see Fig. 1. This angle of θ, which we will call φ, depends merely upon the construction constants of the line.

If

$$Z = r + j\,x$$

$$Y = g + j\,b$$

$$\tan \delta = \frac{x}{\gamma} \quad \tan \epsilon = \frac{b}{g}$$

$$\varphi = \tfrac{1}{2}(\delta + \epsilon)$$

For lines with zero leakage, $g = o$.

$$\varphi = 45° + \tfrac{1}{2}\,\delta$$

Here, then, is a means of plotting the voltage curve. Being the solution of a second order differential equation it will involve two constants of integration and these are F and E_0. These being laid off on the diagram the voltage curve may be plotted by drawing a series of connected chords starting from the point E_0. Each of these chords will be laid off with a protractor φ degrees in advance of the bisector drawn to the point. By a similar construction the current curve may be drawn, except that in this case the constants of integration will be G and I_0, where

$$G = \sqrt{I_0^2 - \frac{E_0^2}{S^2}} \tag{5}$$

From the foregoing it is seen that the current and voltage curves may be defined geometrically as—The locus of a point

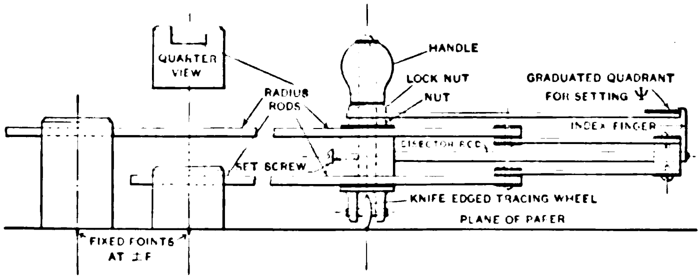

FIG. 3—ELEVATION OF INTEGRAPH

which moves so as to make a constant angle with the bisector of an angle drawn from the point to two fixed points.

Obviously the accuracy of this method will depend upon the shortness of the chords, or, for a given length of chord, upon the radius of curvature. To increase the accuracy the author has constructed an integraph as shown in Figs. 2 and 3. It consists of two steel rods sliding through fixed supports at $\pm F$. The intersection of the rods lies over the point E. Beneath the intersection is a knife edged tracing wheel which is free to move only in the direction of its plane, being constrained from motion in the direction of its axis by the friction of the knife edge on the paper. By means of a graduated segment and a set screw the plane of the tracing wheel may be set at the angle ϕ with the bisector of the angle, and it will maintain this angle as it is moved over the paper, tracing out the locus of E. The paths of the wheel may be preserved by placing a piece of carbon paper over the region to be traced. Aside from electrical curves the instrument may be used to plot any ellipse, hyperbola, or logarithmic spiral.

This method would be incomplete without being able to assign to any point on the curve, the lengths of line corresponding. This length is found as follows: The integration cf equation (4) gives

$$\theta\, l = \log \frac{E + \sqrt{E^2 - F^2}}{E_0 + \sqrt{E_0^2 - F^2}}$$

Let

$$\frac{E + \sqrt{E^2 - F^2}}{E_0 + \sqrt{E_0^2 - F^2}} = \frac{A\, \sigma\, j\, \gamma}{A_0\, \sigma\, j\, \gamma_0}$$

And

$$\theta = (\alpha + j\, \beta)\, l$$

Where,

$$\alpha = \text{Attenuation constant}$$

$$\beta = \text{Wave length constant.}$$

Then,

$$\alpha\, l + j\, \beta\, l = \log \frac{A}{A_0} + j\, (\gamma - \gamma_0)$$

And

$$\beta\, l = \gamma - \gamma_0$$

It may be shown by analytic geometry, taking F as standard phase, that

$$\cos \gamma = \frac{R_1 - R_2}{2\, F} = \frac{\Delta\, R}{2\, F}$$

R_1, R_2, and F being the scalar values.
Hence,

$$\beta\, l = \cos^{-1} \frac{\Delta \mathrm{R}}{2\, F} - \cos^{-1} \frac{\Delta\, R_0}{2\, F}$$

Let the length corresponding to the point E_0 be l_0, then .

$$l_0 = \frac{1}{\beta} \cos^{-1} \frac{\Delta\, R_0}{2\, F}$$

And

$$l = \frac{1}{\beta} \left(\cos^{-1} \frac{\Delta R}{2\, F} - l_0 \right)$$

In lines having zero leakage, the wave length constant

$$\beta = \frac{\omega}{\sqrt{2}\, V} \sqrt{1 + c\, s\, c\, \delta}$$

where V is the velocity of wave propagation, approximately that of light. In this case,

$$l = \frac{\sqrt{2}\, V \cos^{-1} \dfrac{\Delta R}{2 F}}{\omega \sqrt{1 + csc\, \delta}} - l_0$$

Instead of plotting the current curve, the current corresponding to any point on the voltage curve may be found from the relation

$$S I = \sqrt{E^2 - F^2}$$

The magnitude of the current is

$$I = \frac{\sqrt{R_1 R_2}}{S}$$

R_1, R_2, and S being the scalar values.

The angle between current and voltage is the angle between the bisector and the median, of the triangle plus $\frac{1}{2}$ $(\delta - \epsilon)$ degrees.

It is interesting to note the limiting forms taken by the current and voltage curves under extreme conditions.

1. When the frequency becomes very high the reactive constants, x and b, become large compared with the constants r and g which dissipate energy, and the locus approaches a closed curve—an ellipse with $\pm F$ as foci, $\varphi = 90°$.

2. When the frequency becomes very low the dissipative constants, r and g, predominate and the locus approaches a hyperbola with $\pm F$ as foci, $\varphi = 0$.

3. When $I_0 = 0$ (no load) the locus of E becomes the graph of cosh $\theta\, l$.

4. When $E_0 = 0$ (short circuit) the locus of E becomes the graph of sinh $\theta\, l$.

5. When the line approaches infinite length the distorting factor, F, due to the reflected wave, disappears and the locus becomes a logarithmic spiral. This factor also disappears when the impedance of the load is equal to the surge impedance of the line, in which case the generator wave is entirely absorbed by the load and no reflection ensues.

6. When the conditions mentioned in 5 obtain and the reactive constants predominate the locus approaches a circle.

The distortion noticed in Dr. Kennelly's curves for the first wave length or so is due to the reflected wave. As a greater distance from the open end is attained the reflected wave becomes damped out and all the curves approach logarithmic spirals.

J. B. Taylor: While abstracting his paper, Mr. Friendly remarked that while a technical engineer might be disposed to object to some of the automatic devices described, the commercial engineer would be satisfied that the use of the additional devices and complications had justified themselves.

While I have no reason to assume that the particular arrangements described in this paper may be in any way detrimental to the service, I wish to remark that, in general, there is some risk in going so far with automatic devices that the actual telephone service (*i.e.*, the transmission of speech from one subscriber to another, neither of whom is interested in the modes of operation of the devices by which the communication is established) is impaired.

To illustrate this point, mention need only be made of the undesirable and frequently painful, if not dangerous, noises to which we are subjected when using telephones connected to certain common battery systems. The original magneto systems, while undesirable in many respects, were less noisy.

H. M. Friendly: In reply to Mr. Taylor's remarks, if you will look over the circuits carefully you will find that nothing has been introduced in the circuits of the equipment which will attenuate speech appreciably, such as is the case in some types of telegraph equipments applied to telephone lines.

In regard to the noises referred to, we have made a particular effort to avoid extraneous noises of every kind; and in the latter part of the paper our views will be found on that phase. I agree with Mr. Taylor very thoroughly in that extraneous noises on a telephone line, the humming and clicking, is very detrimental to service. The correspondents will invariably pause after a clicking sound and then shout at each other to ascertain if they have been cut off, and it is sometimes a large fraction of a minute before they get under way again after the disturbance has ceased. In all the apparatus designed we made it a first consideration to eliminate disturbances.

Oberlin Smith: It seems to me that any advance toward automatic service should be welcomed and should be developed and discussed. We all know there are tremendous difficulties in telephone exchange work of any kind, sometimes even in pleasing subscribers.

Taking an optimistic view, I do not think there is any question but what in the sometime golden future, I will not say when, all telephony will be automatic, and we will talk all over the world by merely arranging our own instrument, with its buttons or levers, or what not, for the connection desired. We should welcome all improvements in this line as steps towards the ultimate automatic telephony which may extend its arms all over a continent, if not indeed to the ends of the world.

H. M. Friendly: In regard the reliability of the apparatus we have not found the apparatus to give serious maintenance trouble at all. The switch sets look complicated on paper, though in a period of some months test no adjustments were made in any manner to the connecting switch of the through switch switching set, though changes were made in circuit details on several occasions in the development of the apparatus.

Discussion on "Electrolytic Corrosion of Iron in Soils" (McCullom and Logan), Cooperstown, New York, June 24, 1913. (See Proceedings for July, 1913.)

(Subject to final revision for the Transactions)

J. L. R. Hayden: The paper on electrolytic corrosion by Messrs. McCollum and Logan is very interesting by the large amount of data it gives on electrolytic corrosion under actual service conditions, that is, with the iron imbedded in the soil.

The observation that the activity decreases with increasing current density I found very marked in my investigation. I found that under conditions where passivity is possible, complete passivity could be produced by raising the current density, even if only momentarily. Limited time did not allow me to investigate to any great extent the electrolytic corrosion when the circulation of the electrolyte was interfered with by soil or sand, but some experiments showed the same phenomenon observed by the authors, that the passivating action is materially decreased by interference with the circulation of the electrolyte. If the passivity is due to the electrolyte in which free hydrogen ions cannot exist, as has been suggested, this phenomenon would easily be explained.

Alexander Maxwell: (communicated): We are indebted to Messrs. McCollum and Logan for their excellent paper. The work is noteworthy, not only on account of the range and scope of the data presented, but especially because it is in great measure directly useful, and applicable in connection with field work.

A most important feature of these tests is in the relation between the current density and "efficiency of corrosion." As noted in the paper, the results reported by Ganz in 1912 showed, in general, higher "efficiencies of corrosion" than those found by Messrs. McCollum and Logan; and in the former test the current densities employed were much lower than those used by the authors of the present paper.

The authors have used current densities ranging from 0.03 to 5 milliamperes per square centimeter. It may be interesting to compare these densities with some observed by the writer under actual conditions in city streets.

The following values are calculated from a large number of tests made with Haber's "earth ammeter." These tests were all made in connection with pipes which had actually suffered severe damage by corrosion, and most of the tests were made in places where the current density might be expected to be high, as where only a few feet of soil intervened between the pipe and the rail, and when the pipe was definitely and strongly positive to the rail.

Under these circumstances, it was found that the average apparent current density for areas between 100 and 600 square centimeters, varied from 0.0005 to 0.04 milliamperes per square centimeter. While these measurements were not of great accuracy, I believe that they are dependable as indicating the

general order of magnitude of currents leaving pipe surfaces under the conditions noted above.

It would be interesting to extend the investigation of the variation in corrosion efficiency to very low densities such as those indicated above, for I believe that such densities are more nearly representative of average field conditions, and all of the evidence points towards corrosion considerably in excess of theoretical values, at these low densities.

D. C. Jackson: The authors have brought out in this interesting and useful paper many things that have been previously known, or at any rate supposed to exist, but they have been brought out more clearly in some ways in this paper than heretofore; and they have added materially to the available information on this complex subject. A paper of this kind is one we can wisely listen to, as the electrical enterprises have been too prone to overlook the economic importance of consideration for their neighbors.

Let us see what it means in certain industries if stray-current electrolysis is allowed to proceed. I will for illustration take an art aside from electrical engineering. Take gas, for instance, and consider the case of a gas plant that has an output of 200 million cubic feet per annum. That would be a sufficient gas supply for the needs of a city from 30,000 to 50,000 inhabitants, and suppose the leakage from the mains is doubled from the fairly normal rate of 5 per cent up to 10 per cent, due to the fact that the pipes are fairly rapidly corroded or the joints are affected and it is difficult to keep the pipes tight. Illuminating gas is worth in the Eastern States, delivered at the outlet to the holders, approximately 30 cents a thousand cubic feet, which makes the extra leakage due to electrolysis cost $3000 per year. It costs the company that much to generate and put in the holder the gas lost from the mains on account of their deteriorated condition. Capitalizing that means a good deal of money, in addition to the other various disadvantages that arise from leaky gas mains; and that is for gas mains alone, and leaves out other underground structures. It also makes no allowance for the extra cost of repairs to the mains, which is necessary on account of their leaky character.

If, instead of a little city, in which 200 million cubic feet of gas are sold, we take a large city with a sale of 5000 million cubic feet of gas, under similar conditions of doubling the leakage from 5 per cent to 10 per cent, on account of the corroded mains, and we consider that the gas costs the company at the outlet of the holder 30 cents a thousand, the increased loss of gas becomes a matter of $75,000 a year.

That illustration shows very clearly the problem which Mr. McCollum has been working on, which is of considerable importance. The question is really an economic one. It relates to the expenditure that might be made for protection of underground structures from the ravages of electric railway currents

and the balancing of the annual cost of protection against the annual cost of the injury that the stray currents produce.

Hugh T. Wreaks: I notice that all of the experiments were made on uncoated pipe, and I am curious to know whether future experiments would take in the line of coated pipes, that is, enameled, sherardized or galvanized, because in a recent lecture I attended over in Brooklyn, one of the city engineers described the preparation of their water pipes so as to resist corrosion, and laid great stress on the value of enameled coating; this coating being covered by fairly definite specifications on ductility, strength, melting temperature, etc.

If this has not been touched upon in other papers, I believe it is germane in this discussion.

Harold V. Bozell: Prof. Jackson's mention of gas mains calls to mind a practise in Oklahoma, where usually gas and electric interests in one town are under one ownership and there is mutual interest in looking for solution of the electrolytic problem. I don't know how this has worked in the East if it has been used, but it was found there that by running gas mains on both sides of the street much less electrolysis resulted; of course the greatest electrolysis occurs in the cross pipes and this was eliminated. It should be stated that paving, access to pipes and other items added to cause the double main system.

Harry Barker: I would like to ask if the soil studies at the Bureau of Standards were carried into alternating-current work. Question continues to arise generally as to the electrolytic effect of alternating current. We would expect of course that where the reversal of the current is rapid, there is little time for secondary chemical reactions to intervene; then on the reversal of the current the original electrochemical reaction itself is reversed. Where the time involved is considerable, the secondary changes may prevent complete reversal. Some experimental results confirming this are available but a wider range is still desirable.

I presume, from the completeness with which the Bureau of Standards has undertaken its corrosion studies, that they must have well considered such points. But the Bureau has said comparatively little about its alternating-current work and, if it would not be publishing the results too early, perhaps Mr. McCollum might add a word on it.

F. C. Caldwell: With regard to the last point in the paper, that is the limitation of the voltage, I would ask if it is true that it is not wise for a municipality to set a limit to the voltage to be permitted in the tracks, because of the fact that if they do so they are liable to relieve the railway company from responsibility in the matter. That is, if the railway company complies with the requirements of the municipality and keeps its voltage within the prescribed limit, the fact that such limit has been prescribed relieves the railway company from any further responsibility for electrolysis which may take place within that limit.

J. C. Lincoln: I inquire if the authors have any information as to the effect of breaking the pipes, that is, breaking the electrical continuity of the pipes, in lengths of a few hundred feet, or several thousand feet, whether they have any information as to what the effect of such breaking is on the electrolytic effect?

Henry G. Stott: I want to say one word as to the question of the responsibility of the railroad companies, which has been brought up. I would like to remind the gentlemen present that there was a very able paper presented before the Institute some three or four years ago by Mr. George I. Rhodes, which treats this subject very fully, and I think that paper was really a classic on the question of electrolysis, and upon its cure, which is more important. Broadly speaking, the voltage drop in the return circuit has very little to do with the amount of damage, that is my experience. It is more a question of where you lead the current back. By insulating the negative return to the substation or power station, as the case may be, by this method it is possible almost entirely to prevent the leakage of current from the rails to surrounding conducting bodies, and that is the method which the companies with which I am connected have adopted most successfully in some very trying cases.

I simply wish to remind the members who are interested in that subject of the paper written by Mr. Rhodes, as it was one of the clearest expositions on the subject ever presented to the Institute.

Albert F. Ganz: The paper is full of valuable results and conclusions. It describes a very large number of tests made in a laboratory with the accuracy obtainable only in a laboratory, and yet made under conditions exactly resembling those found in every-day practise. Perhaps the most important single result reported is that electrolytic corrosion of iron in ordinary soil, with the low current densities usually met with in practise, follows Faraday's law. This means that under the usual practical conditions met with in electrolytic corrosion of underground iron structures, we can compute the weight of iron corroded on the basis of approximately 20 pounds of iron per ampere year.

The authors have shown that corrosion efficiency varies with current density, and that with current densities of an order greater than a few milliamperes per square centimeter the corrosion efficiency decreased from 100 per cent to low values with increasing current density. For very low current densities, of the order of a few hundredths of one milliampere per centimeter, they have generally obtained corrosion efficiencies somewhat larger than 100 per cent.

They state that they have not been able to obtain the high efficiencies of corrosion, up to 500 per cent, which I found in some of my tests reported last year. I wish to say in explanation that these high efficiencies of corrosion were obtained only in the tests where the surface scale had not previously been removed

from the test pipe, and where the pipes had only been cleaned to remove dirt and grease. In the tests which I made where the pipes were first turned down in a lathe removing all surface scale, I obtained efficiencies of corrosion varying between 103 per cent and 123 per cent, which values agree well with those found by the present authors. The very high values found by me were therefore due to the effects of the surface scale.

During the past year I have made a few tests for efficiency of corrosion with soils obtained from several cities, using low current densities of less than one milliampere per square centimeter, with iron anodes cleaned of scale, and I have found values generally somewhat above 100 per cent.

It may be of interest to compute the probable density of current leaving iron pipes in ground and returning to trolley tracks under assumed practical conditions. The resistivity of soil given in the paper varies between 400 and 6000 ohms in a centimeter cube. Assuming a distance of three feet (91 cm.) between a pipe and the rails to which the pipe is positive in potential, the resistance of an intervening column of soil one square centimeter in cross-section would vary between 36,000 and 540,000 ohms. With one volt potential difference there would result a current of from 0.03 to 0.002 milliampere through the column of soil; this corresponds, therefore, to the average density of the current leaving the pipe surface under the assumed conditions for one volt of potential difference. With 5 volts potential difference, a value commonly found in practise, the resultant average current density would vary from 0.15 to 0.010 milliampere per square centimeter.

As to the values of current density which may be considered dangerous to an underground pipe, it should be remembered that in nearly all practical cases of destruction by electrolysis from stray electric currents, localized pits are produced, which shows that the current generally leaves from localized areas. It is pointed out in the paper that a current density of 0.05 milliampere per square centimeter would cause corrosion to proceed at the rate of one centimeter in seventeen years; this is equivalent to approximately $\frac{1}{8}$ in. (0.32 cm.) in five years; current leaving a steel or wrought iron pipe with a $\frac{1}{8}$-in. (0.32 cm.) wall, of a density of 0.05 milliamperes per square centimeter, would pit entirely through the metal in five years, provided that the current left the pipe surface uniformly and corroded the pipe uniformly. If, however, the current should leave from 10 per cent of the pipe surface, this same average current density of 0.05 milliamperes per square centimeter would corrode through the metal of the pipe in one half-year, and a current density of only 0.005 milliampere per square centimeter, leaving from 10 per cent of the pipe surface, would pit through the pipe in five years. This very low current density would therefore be dangerous to the pipe.

Regarding the effect of moisture, the authors have found that

as soils are dried the corrosion efficiency is decreased. They suggest that this may be due to the fact that with dry soil the iron is in less uniform contact with the soil, so that the current discharged from localized areas results in higher current density of discharge at these points. This is the logical and probable explanation. I do not believe, however, that this in itself gives much promise of diminished danger to pipes from electrolysis, because while the total amount of corrosion may be less, this may be so concentrated as to be quite as affective in producing pits through the metal of the pipe.

Professor Caldwell has stated that in his opinion it would be undesirable for a municipality to limit the voltage drop in rails by an ordinance, because this would stop them from obtaining damages from electrolysis so long as the terms of the ordinance are complied with. In reply to this statement I would like to say that legal authorities have advised me that the enactment and enforcement of a city ordinance does not take away from a municipality or from the public the common law right to sue for and obtain damages that may be caused by stray electric currents even if the terms of a special ordinance designed to minimize such dangers, are complied with. The reason is that the common law is superior to a city ordinance.

Burton McCollum: In regard to the point brought up by Mr. Hayden's written communication on the passivity of iron, it would be out of the question here to enter into a discussion of the cause of passivity in iron. It is a matter which has been investigated a great deal, and has led to a great deal of controversy, but I do not agree with Mr. Hayden that passivity is found only when the iron is in an electrolyte in which hydrogen ionization cannot exist—that is in an alkaline electrolyte.

We are all familiar with the fact that iron is passive in any strong alkaline solution, but we also know that iron can be rendered passive and remain passive in very strong acids. As a matter of fact, there is a great deal of evidence accumulated to show that there are probably a number of different causes of passivity, in addition to those that occur in an alkaline solution.

As to some of the points brought up by Prof. Jackson; he speaks of the effects of moisture on the efficiency of corrosion and on resistance, and seems to be inclined to attribute most of the lack of electrolysis in dry soils to the high resistance. I think, probably, that that is the case, but it might be pointed out that the tendency of the low efficiency of corrosion is to produce the same result as that which would be caused by the reduction of current by the high resistance, so that these causes are superposed, and it is difficult to say how much reduction in corrosion may be due to one and how much due to the other. Probably the resistance is the most important factor.

As regards concrete roadbed, I think it will as a rule give a higher resistance than a dirt roadbed, in which the rails are pretty well buried in the soil. I have made tests of the specific

resistance of water-soaked concrete at the Bureau of Standards, and find that it ranges from 5000 to 8000 ohms per centimeter cube, which is very much higher than the resistance of many earths, but perhaps not much higher than the average of all. The superiority of concrete roadbed is great only where earth resistances are low, but in many cases I think it will greatly reduce leakage currents.

The question was raised as to whether Faraday's law always holds. In order to answer that it is necessary to say just what we mean by Faraday's law. As Faraday's law was originally stated, it applies to the decomposition of the electrolyte. In modern electrochemical processes, we think of it as applying to all reactions which take place at the electrodes. When we think of it in that sense, Faraday's law always holds. If an iron anode is corroded at 100 per cent efficiency, then one gram equivalent of iron will be corroded by the passage of 96,540 coulombs of electricity, and Faraday's law holds true as applied to corrosion of the anode. If, however, the iron is in a solution which renders it passive, there will be no corrosion of the iron, and in that case the electrolyte breaks up in accordance with Faraday's law, and 96,540 coulombs of electricity will result in the breaking up of one gram equivalent of electrolyte.

If, for instance, an iron anode corrodes at 60 per cent efficiency, then 0.6 of a gram equivalent of iron will be corroded by 96,540 coulombs of electricity, and at the same time 0.4 of a gram equivalent of the electrolyte will be broken up, so that Faraday's law still holds when we consider all of the reactions which take place at the anode.

As to the relative amount of current in pipes in warm and cold weather, it would appear that if the depth of rail is not more than 9 inches and if the earth is frozen to a greater depth than this throughout the entire system, the amount of leakage from the track is bound to be much less than it would be in case there were no frost in the ground, and that would lead me to believe that the current flowing in the pipe under those conditions would be considerably less than if the ground were not frozen.

I want to endorse highly the statement made by Prof. Jackson in regard to the matter of balance between the actual damage and the cost of protection. It is neither necessary nor desirable to eliminate entirely all electrolytic trouble, but the desirable thing is to reduce the loss to such a value that any further reduction of loss would be more expensive than to repair the loss.

Mr. Wreaks brought out the question of coated pipes. We now have in course of preparation a report dealing with the subject of corrosion of coated pipes. I may anticipate the results to the extent of saying that of a very great number of commercial pipe coatings which we have tested we found very few which we considered to be of any value. In fact, they are rather detrimental, because they tend to concentrate the corrosion. There

are some coatings, however, such as extremely heavy layers of pitch, which may give protection for a considerable time, but it is doubtful whether the protection thus secured is worth the cost. Besides, such treatment is merely symptomatic and does not get at the cause of the trouble and for that reason surface insulation, if used at all, should be supplementary to means applied to the tracks for reducing leakage of stray currents from the rails.

As to enamel coatings for protecting pipes, I think that is a question as to whether they have suitable mechanical properties, and it is also a question of whether they are waterproof. If they are absolutely and permanently waterproof, they will remain insulating and protect the pipes, but if they develop slight flaws and permit the least trace of moisture to soak through and come in contact with the pipes, local corrosion and pitting will occur.

Mr. Bozell brought up the point of placing the pipes on both sides of the street. That is a good thing to do, and it is done a good deal in many places at present. I am confident, however, that that is not sufficient in itself to reduce electrolytic troubles to a satisfactory minimum unless something is done in the way of providing a proper negative return for the current. Besides, we have the problem of protecting pipes already in place as well as those to be laid in future.

Mr. Barker brought up the subject of alternating-current electrolysis. A good deal has already been published on that subject, and among others I may mention a paper by Mr. S. M. Kintner, published several years ago, in the *Electric Journal*, in which he gave the results of some experiments which he carried on with alternating current under practical conditions, and found the corrosion was but a fraction of a per cent of the amount of corrosion caused by direct current. Our own experiments have verified these results, and I do not believe that electrolysis from alternating currents is likely to become a serious problem, except in very special cases.

As to the matter of limitation of the voltages, and such limitation relieving the railway companies of responsibility, as suggested by Mr. Caldwell, I would not approve of any specific limitation of voltage that would relieve the railway companies of responsibility, unless it had been absolutely proved that such limitation was sufficient to relieve electrolysis troubles in a satisfactory manner. Until further data on this point are secured, I do not think it is wise to enter into any agreement that will relieve the railway companies of responsibility for the damage.

The subject of resistance joints in pipes was brought up, but as this subject is being treated at length in a report of the Bureau of Standards, which is now in preparation, I will not attempt to discuss the matter here, other than to say that if properly applied it may have some value as a secondary means of electrolysis mitigation, but the difficulty with it is that if the

resistance joints are not inserted with sufficient frequency there will be such a large drop across the joint as to injure the joint itself, and unless it is accompanied by some primary means of mitigation, in which the potential gradients in the earth are reduced to a low value, it is likely to become very expensive.

I think the subject brought up by Mr. Stott, that of using insulated negative return feeders, is deserving of the most careful consideration. We have given much study to this method of reducing leakage of stray currents into the earth. I am convinced that when properly applied it offers one of the most effective and economical means of attacking the electrolysis problem. This subject is being treated at length in a publication which the Bureau of Standards is preparing to issue shortly, dealing with the subject of Electrolysis Mitigation.

As to the question of current density brought up by Mr. Maxwell, and again by Prof. Ganz, I might point out that the very low current density which he referred to, say 0.005 of a milliampere per square centimeter, if uniformly distributed could not produce any serious damage. Such a current uniformly distributed, even if 100 per cent corrosion efficiency be assumed, would not produce any serious corrosion in less than 100 years. However, the method of measuring the current was such that they measured average current, and undoubtedly the actual density of current discharge was greater than that, and that was responsible for the corrosion which resulted unless there was a good deal of soil corrosion also. I think, therefore, that the current densities used in these experiments will pretty nearly include the limits within which damage may become serious in practise, though perhaps they should be extended a little further on the lower side, in accordance with the calculation of Prof. Ganz. By current density, we mean not average current density, but the current density at the point where the current is going off the pipes or where pitting takes place.

DISCUSSION ON "THE ELECTRIC STRENGTH OF AIR—IV" (WHITEHEAD), "THE POSITIVE AND NEGATIVE CORONA AND ELECTRICAL PRECIPITATION" (STRONG), "LAW OF CORONA AND DIELECTRIC STRENGTH OF AIR" (PEEK), AND "AN OSCILLOGRAPH STUDY OF CORONA" (BENNETT), COOPERSTOWN, NEW YORK, JUNE 26, 1913. (SEE PROCEEDINGS FOR JUNE, 1913).

(Subject to final revision for the Transactions.)

C. F. Scott: The papers that have been presented are part of a series which have been appearing in our transactions, building up a new literature. It was, I believe, fifteen years ago when the first paper on this subject recorded a number of experiments and tests by Mr. Mershon on the lines of the Telluride Powder Company, in Colorado, and the tests were made jointly by the coöperation of Mr. Nunn of that Company, and Mr. Mershon and the company he represented. That paper presented the effect of these losses and the method of measuring them, and the success of the tests was largely owing to the ability and ingenuity of Mr. Mershon in meeting new requirements under particularly difficult conditions.

The large fact presented was that above certain voltages there was corona loss as it has since been named. Professor Ryan became interested and undertook a study of these laws and conditions, and in a year or two came a paper by him giving the results of his laboratory work. Presently Mr. Mershon presented results of other tests in the field. Others have taken up the investigation. The paper presented this morning is the fourth paper in a series, another paper is the third paper in a series by the respective authors, dealing with this subject. Fifteen years ago a new fact was presented, and a new field of investigation was opened.

In the meantime, power transmission has gotten up away beyond the early voltages, and these matters of corona have become very important engineering factors and engineering limitations. New methods and instruments, both theoretical and investigative, are employed. New knowledge, new physical theories, are here applied, and this wonderful instrument, the oscillograph, is now applied to this very remarkable condition of measuring the charging or corona current in a little wire a dozen feet long.

This Institute as a whole, the engineering profession, this whole department of high-tension transmission, are very much benefited by these papers, and I think I can speak for all when I congratulate and commend the authors on the excellent character of the work and its importance, both from the theoretical and the engineering point of view.

L. T. Robinson: The details of the work that has been done here are of very great interest; they will become of more and more interest as time goes on. But we have now heard a great deal of this work, we have many records, and perhaps at this

time it would be possible to go back a little to give the work an important practical application.

The one particular point that seems to be involved here, indirectly, is the question of the measurement of voltages. We have here, apparently, another means that may be employed, that is the measurement of voltage by the appearance of corona before the disruptive discharge takes place, and in many instances I think that would be a very valuable thing. We have, of course, other methods that are applicable in perhaps the majority of cases, but if I read the paper of Messrs. Whitehead and Fitch correctly, there appears to be a very sharp point where the phenomenon is observable, and if it would not be leading this discussion a little to one side, I would like to have something said by the authors and by the other gentlemen present as to what would be the advisable procedure in the case of different voltages and different conditions which must be met.

Professor Bennett's work, in which he speaks of the small angles between the currents in the transformers, of the nature of a degree, is very good testimony of the care with which he has looked over his results, and he has drawn the line rather finely, but it is quite evidently there, when you come to look for it. If we may digress just a little more, for an instant, I think it is a thing that may be taken as an indirect lesson by all of us, that is, we do a great deal of work and make lots of diagrams and make many figures on paper, etc., and make a lot of observations, but we do not half look at these things. If we examined them more carefully, we would not need to take so many observations. The small transformer to make the current observation in the oscillogram has been used many times, but I do not think the possibilities of operating in that way have been brought out so that it is quite generally appreciated. It might be of interest to say that in an ordinary electromagnetic instrument, for instance, a moving iron instrument, there is required in the neighborhood of from two to five watts to operate the instrument. In the oscillograph, although the current is rather large, the total energy required is rather small, and, unless I make some mistake in multiplying it, it corresponds to about 1/400th of a watt, so that there is a possibility of doing a great deal with suitable transformers, and no doubt the transformers could be much improved, and would be well suited for any other purpose, and the necessary corrections supplied. Even a sensibility of 1/400 watt leaves a good deal to be desired, because when you come to another instrument, that is the moving coil instrument of the type first commercially developed by Dr. Weston, we have something like 1/1000th of a watt as necessary to send it across the scale.

J. B. Whitehead: Mr. Robinson's suggestion that we consider the corona as a measuring instrument is one near to my heart, but I will not try to divert the discussion that way for a moment, but will get back to it later, perhaps.

Alan E. Flowers: In regard to electrical precipitation of suspended particles from gases, it ought to be emphasized here, that the subject has a very respectable history in physics, and that we are particularly indebted to the physicists of England for the ground work of the subject. C. T. R. Wilson showed that water vapor tended to condense upon ions and so precipitate. Lodge showed that foggy, out-door air could be cleared in the neighborhood of highly charged electrical conductors.

Out on the Pacific Coast, Professor F. G. Cottrell has been working on electrical precipitation for several years and has obtained some very satisfactory results. About a year ago, Professor R. C. Carpenter described a settling chamber or room, fitted with baffle plates, where the gas velocity was so reduced that something like 98 per cent of the dust was removed. The electrical methods were, at that time, capable of removing about 93 per cent of the dust. These figures are only approximate and any error in their statement should not be attributed to Professor Carpenter.

I should like to have from Mr. Peek more explanation of the large values for the " critical distance " which increases as the square root of the radius, does it not?

F. W. Peek, Jr.: Yes.

Alan E. Flowers: So that with a sphere of 12.5 cm. diameter, the critical distance attains values of nearly one cm.

In Professor Bennett's paper, attention should be called, particularly to the use of the term " hypothetical gradient " and the author given our thanks for the use of the term. It seems to me that the values obtained by calculation, which we have been in the habit of using, must be subject to large corrections under corona conditions.

Taking up the question of voltage measurements raised by Mr. Robinson, I would like to call attention to an article published recently in England by Milner. In high-voltage measurement, probably the greatest difficulty is that due to the effects of frequency.

Milner's work throws much light on this point. He used the Braun tube to investigate the relation between the voltage and current in a small sphere gap, carrying an oscillatory high frequency discharge. Instead of voltage-time and current-time curves, Milner thus obtained volt-ampere curves, from which, assuming a sine current, the time curves were calculated. In Fig. 1, are shown the resultant curves for a discharge, oscillating at a frequency of 2,000,000 cycles per second. The initial peak of the volt-time curve is about 3000 volts; the voltage then drops to the arc value of about 35 volts. Succeeding loops all show an inital value of 300 volts, corresponding to the glow value, followed by the low arc value of 35 volts. The current showed a damping intermediate between the linear and logarithmic rate. The variation of the effective resistance in the oscillatory circuit doubtless has something to do with this rate of decay.

The high initial value of 3000 volts was obtained only once in each wave train, but the 300 volt glow value, was necessary in each alternation, being followed by the arc value of 35 volts. These voltages are the same as the values one is accustomed to from work at commercial frequencies.

It would seem that this work is at least an indication that we may use the breakdown of air between spheres as a measurement of voltage, independent of frequency. These results also show the tremendous rapidity with which the fully ionized condition disappears.

Professor Bennett mentioned that in any cycle, corona ceases at voltages of 2 and 3 per cent lower than the value at which it began and also, laid some stress on the possibility that antecedent ionization, either in the same or preceding cycles, had something to do with the critical voltage. From Milner's work, one would conclude that recombination is too rapid for antecedent ionization to affect the critical voltage.

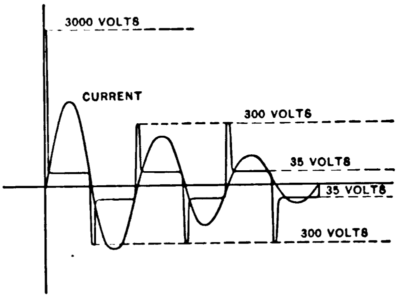

FIG. 1

On page 1486 and in the corresponding curves Fig. 7 it is shown that the voltage at which the corona begins in any cycle is appreciably lower, when the voltage is much in excess of the critical value. It might be pointed out that this, as well as the lower voltage for cessation of corona in any cycle, might with greater probability be ascribed to the temperature of the electrode surface. The bombardment of the surface being such, as to raise appreciably the temperature of a very thin surface film.

I would also like to ask Professor Bennett why the polarity, giving the greater power loss, is not the one allowing the breakdown at a lower voltage.

J. B. Taylor: It is interesting to note that Prof. Bennett has made use of a method which I suggested several years ago, though I believe Prof. Bennett has been the first to show records obtained by using it.

I refer to the differential connection of a current transformer in which the charging current, due to electrostatic capacity of

the wire on which corona is being studied, is balanced out by a condenser of proper capacity.

The construction of the balancing condenser should be such that it is free from corona. This leaves the corona current alone for recording or noting in instruments such as the oscillograph, ammeter, and wattmeter or other device.

I wish to ask if the doubling of the potential waves as shown in records 179 and 180 has any special significance, or does it result merely from a double exposure obtained accidentally in making the records.

W. H. Pratt: I am very glad Mr. Robinson raised the question as to the adaptability of methods of using corona for measuring high potential. It is a matter I have had in mind for some time and was hoping to hear at this meeting some facts which would either confirm or else change my opinion as to the possibility of making use of this phenomena in this measurement. I have nothing in detail to suggest, but would like to hear if there are others who have any ideas on that subject.

Alan E. Flowers: I would like to bring up another point, in regard to Professor Bennett's work in getting oscillographic records of the corona current, that is the possibility of using the Einthoven string galvanometer for the measurement of these very small currents. Its use would eliminate the difficulty of self-induction in the transformer and the oscillation that occurs when the corona discharge suddenly starts.

P. M. Lincoln: I ask whether there is any one here who has made or observed or knows about the current of corona for high-voltage direct current. I think that will be an extremely favorable way to study corona and just why it is.

Alan E. Flowers: Answering Mr. Lincoln's question, I recall that Watson presented a paper at the Winnipeg meeting of the British Association for the Advancement of Science, in 1909, published in the *Electrician* Vol. 63, page 828, Sept. 3rd, 1909. In this paper, experiments were described giving values of the corona current with direct current at voltages up to 100,000 volts. The critical voltages were the same as those found by Ryan for the maximum instantaneous alternating current voltages, when using the wire and concentric cylinder. For parallel conductors, out doors, under atmospheric conditions, much lower values were found and the critical voltages corresponded much more nearly to those found by Mershon at Niagara.

P. M. Lincoln: What is the order of the losses which occur in that manner in comparison with those which occur in the breakdown with alternating current.

Alan E. Flowers: I do not recall the figures for the losses, but my impression is that the losses were of the same order as with the alternating current, though smaller.

John B. Taylor: I think Mr. Lincoln's point is very pat, and there is something wrong in the formula which puts frequency

directly into the formula. When we come to direct-current the frequency should be taken as zero, and there is either a different set of conditions found to obtain of the formulae must be regarded as approximate, to be used only within a limited range of frequency.

P. M. Lincoln: That is the object I had in mind in asking for the order of the losses with direct current. I thought probably the loss which would take place if the voltage were established on the wire and kept constant, compared to the loss which is due to the initial breaking down of the film is so small as to be entirely masked at frequencies of 60 cycles or thereabouts. That would lead the ordinary observer to believe that frequency enters directly as a factor, whereas as a matter of fact, at very low frequencies there is an appreciable loss.

John B. Whitehead: Before answering the one or two questions which have been asked specifically as to my paper I want to make one or two comments of my own on the papers of the other authors.

I want to call attention to some average values that are given by Professor Strong as to the size of gaseous ions and the velocities with which they move. If one wishes to get a conception of the mechanism suggested by the ionization theory for the conductivity of gases, these figures are rather suggestive.

Passing to Mr. Peek's paper he will excuse me if I take another crack at his " energy zone." He knows there is nothing but good feeling in this. I should like to know why it is necessary to go to the extent of the suggestion he makes. If I understand it properly, the suggestion is, as you increase the voltage on the line, you are storing electrostatic energy in the electric field, and there finally comes a time when the medium immediately around the wire cannot stand any more energy. That is all right as far as it goes, but the thing which entirely robs the suggestion of any interest to me is that there is nothing constant about either the volume density or length over which the discharge takes place, in other words, the zone is different in length for every size of the wire. That brings us back to where we were before.

I am particularly glad to read Mr. Peek's observations on pressure. I believe it is the first time they have been published in detail, and they, of course, offer a very interesting substantiation of the relation which he has given connecting the critical gradient with the density.

I also find that Mr. Peek is adopting the language of the ionization theory. At the top of page 1535, he suggests the mechanism by which the corona may be started, and that there may be free ions at the surface of one of the conductors. It is not necessary to assume that there are any ions at the surface. There are always a number of free ions in the air owing to the continual state of upsetting and recombining of the ions in the molecule. In normal air there are about 1000

free negative ions per cu. cm., and the number may increase four or five times under certain conditions. It is possible to increase the number enormously by various ionizing agents. When a difference of potential exists between conductors these ions are put in motion by the electric field. They are free charges and move in the direction of the gradient.

Passing to Mr. Bennett's paper, I want to express my very great admiration for the care with which the experiments have been performed and to state that I regard it as one of the most valuable contributions to this subject which we have had in some time. There are some points I want to raise in connection with it. On page 1480 in differentiating between the instant of ionization and voltage of copious ionization, the suggestion is made that there is some ionization due to the electric field before the instant of copious ionization. With the very sensitive method for observing the presence of ionization with the electroscope, I have never found the least evidence of any ionization preceding the actual instant of copious ionization.

Mr. Bennett says: "The hump is first detected during the half cycle in which the wire is anode and the cylinder cathode." If the wire is anode, the negative charges are moving in towards it and they are consequently moving into a region of intense field, and they will be accelerated more rapidly during their mean free path. This is in accord with the theory of secondary ionization. During the time which elapses between two collisions with molecules, if the ion has moved into a more intense field, it acquires greater velocity than if it had moved the opposite direction. Mr. Bennett points out that he was unable to observe this on the records, and refers to oscillogram 183. Oscillogram 183 appears to me to substantiate his statement. That oscillogram is as I would expect to find it, and I do not see any evidence on it of a starting of corona on the other half of the wave, when the wire is cathode.

Referring to page 1482; when slowly lowering the voltage, reference is made to the fact that the hump does not disappear from the current wave at the same voltage at which it began. I venture to suggest that this may be explained as a temperature lowering. The appearance of corona is sensitive to a change in temperature. The actual presence of corona, representing energy expenditure, elevates the temperature of the gas in the neighborhood of the wire. We have found through a long series of osbervations a number of discrepancies for which we could not account until we finally traced it to the elevation of temperature of the wire due to slight rubbing for cleaning purposes between observations. We found by letting it stand three or four minutes, to be sure that the whole apparatus came to constant temperature, that the trouble disappeared.

In paragraph 5, Mr. Bennett says that the oscillation in the current occurs when the wire is cathode to the cylinder. If the wire is anode in the neighborhood of starting of corona, the corona

is confined to a comparatively small region. When the wire is cathode, and you have the actual process of ionization or copious corona, you have a more free generation of ions due to the fact that the whole region is largely broken down, and so has high conductivity.

In paragraph 2, on page 1485, Mr. Bennett says: "With increasing impressed voltages, the instantaneous voltage at which the copious ionization sets in becomes smaller and smaller," and then refers to Fig. 7 to show the amount of that reduction. I am not sure that the temperature would account for as great lowering as he observes, but I want to suggest, at least, that it may be a possible explanation. It is extremely important to look for temperature variation.

At the top of page 1486 a statement is made: "The current is quite appreciable before the start of copious ionization." I venture to suggest that this is a residual effect, due to the foregoing corona. Recombination goes on with enormous rapidity, as indicated by the fact that the corona does stop. But this does not mean you have no ionization; the process of ionization is stopped, but there are plenty of free ions left and they constitute the current indicated by the slight accent in the curve of film 188.

Coming to page 1489, with reference to the great difference in the losses in concentric cylinders and parallel wires, I think the explanation is obvious,—This process of loss to my mind is made up of two factors, one is the process of ion ization,or breaking down of the molecules, which undoubtedly requires energy. The other and larger part of the loss is due to the actual conduction current, caused by the passage of ions from one conductor to the other.

L. T. Robinson: Does not the loss vary directly as the frequency?

John B. Whitehead: I do not believe it varies directly. The difference in the paths of the ions in concentric cylinders and in parallel wires, would account for the difference in loss observed by Mr. Bennett. In the concentric cylinders you have perfectly straight paths for the ions, and very much shorter than in the widely scattered paths which approximately follow the electrostatic field between parallel wires. The actual loss must vary in some way with the frequency. If you get a breakdown on every wave, you pile up the loss with increasing frequency, but I do not believe there is a strictly proportional relation.

In regard to Mr. Robinson's suggestion as to measurements. In our laboratory we have been conducting experiments for the perfecting of the wire and cylinder apparatus as measuring instruments for some time, and I hope to be able to present the results of that investigation to the Institute in the near future.

The accuracy with which one can repeat observations on the formation of corona on a clean wire in a cylinder is very much closer than the possible control of the usual alternating-current

circuit. There is no question in my mind that if we can reduce the apparatus to a convenient form, so that it may be carried about, we have an instrument which is incomparably better, as regards final accuracy than either the needle or the sphere gap. A serious limitation of such an instrument is that for a given voltage there is only one size of wire. If several different voltages are to be measured with the same apparatus a number of wires are necessary. However they may be inserted readily and frequently, in a clean condition, corresponding to different voltages and I have not found that this is a serious complication. We have an apparatus, comparatively limited in range, as yet, with which we have worked for some time. Taking voltages almost daily since the first of October last year, and correcting for temperature and pressure, we have had no difficulty in checking these voltages over a wide range of conditions to a fraction of a per cent.

We are also investigating the surfaces of metals, as regards their permanency, looking to the possibility of eliminating the necessity for cleaning. We have not got far enough along with this to say what the best material would be. We are also trying various wave shapes, as the voltages measured have so far been considered, and I believe properly, to be the peak voltage, the highest voltage on the wave.

There is another limitation to such an instrument, that I regard as perhaps more serious than any and that is the fact that the observing instrument which so far has been found to be the most suitable for the observations is the electroscope, and the electroscope, unfortunately, is not a convenient instrument to carry about. It is not suitable for a shop test of high voltage. It is obviously impossible to use the visual appearance of the corona as the measuring instrument. To do this a room absolutely dark is needed and one must be in the room several minutes before he can see the first appearance of corona. We have developed another method of detecting the beginning of corona. We punch the outer cylinder full of small holes, and surround it with another cylinder so connected to the cylinder which forms the grounded side of the circuit as to make it sound-proof. Two openings in the outer cylinder are connected by two broad rubber tubes to two ear pieces strapped over the head. You can hear the corona start in a quiet room, and fix the point at which it does start on a clean wire just as closely as by looking at it. We have checked this with many tests made by two independent observers. I believe there are great possibilities in the concentric cylinder apparatus as measuring instrument.

I would like Mr. Flowers to give the references to Milner's paper and tell how these interesting curves at two hundred million cycles were traced.

With reference again to Mr. Lincoln's question as to experiments with high-voltage direct current, Watson's observations

were made with the induction static machine as the source of voltage, and while his observations were extremely interesting, I believe they are qualitative rather than quantitative. I do not think there should be any difficulty, however, in understanding the loss at continuous voltage if you go back to the idea which I have suggested, and which I think is unquestionably so, that a large part of this loss, not the principal part of it, is due to the actual passage of current between conductors.

P. M. Lincoln: If the conception which Dr. Whitehead has just given is correct, our law of loss due to heating needs revision. Frequency does not apply there.

F. W. Peek, Jr.: Answering the questions asked in reference to variations of corona loss with frequency: The greater part of the loss over the commercial frequency range is a per cycle loss or varies directly with the frequency. There is also added to this a small constant loss independent of the frequency.

The complete loss equation may be written:

$$p=k\ (f+a)\ (e\text{-}e_0)^2 \text{ kilowatts per kilometer of circuit.} \qquad (1)$$

Then at zero frequency f becomes zero and the loss is

$$p=k\ (a)\ (e\text{-}e_0)^2 \text{ kilowatts per kilometer of} \qquad (2)$$

The constant a is comparatively small.

Therefore where f is comparatively large a becomes negligible and the loss may be written:

$$p=k\,f\ (e\text{-}e_0)^2 \text{ kilowatts per kilometer} \qquad (3)$$

The equation is generally written in the form (3) for convenience in working at the higher commercial frequencies near 60-cycles and practical size of conductors. When I first gave this equation in my paper in 1911* I stated it did not mean zero loss on direct current. The zero frequency loss indicated in (2) is not necessarily the d-c. loss, but one would expect the d-c. loss to be higher. There must be loss on the d-c. because as soon as a given flux density is reached the air must break down. This requires an expenditure of energy. There must also be a flow of energy to keep the air in this broken down state as the ionized particles move away. Some three or four years ago I made some measurements of corona loss on a wire in a tube. I found that if air were sent through the tube the loss increased with increasing air velocity. The faster the broken down air was moved away the greater the loss.

Watson has made loss measurement of d-c. corona on wires. While these loss measurements are rather qualitative than quantitative, they indicate a d-c. loss of about $\frac{1}{4}$ to $\frac{1}{2}$ the 60-cycle a-c. loss at the same maximum voltage.

I have frequently used corona as a means of measuring very high voltages as a check on other methods.

*Law of Corona, A. I. E. E., June, 1911.

Sometime ago I found that the needle gap varied a great deal from time to time at constant temperature and pressure. This variation is caused by humidity. Around the needle gap there is a great brush discharge before spark-over. The water in the air which exists as a gas is probably changed into vapor or a "fog" around the needle points by the brush discharge. This has the effect of increasing the size of the conductors and causes a higher spark over voltage. Humidity has no effect on the starting point of corona, or spark over on spheres, because there are no brushes to cause change from gas to vapor. I mention this because it has a bearing on precipitation.

Prof. Bennett's loss investigation confirms the "quadratic law" which was first derived by me in 1910, and given in discussions in Jan. 1911 and more completely in the "Law of Corona," June 1911. The difference is quantitative. This is because of the small size of wire used, which is much smaller than any used on commercial lines. Where the wire is smaller than about 0.25 cm., e_0 is larger than that expressed by the simple practical equation, and I have given a more complete equation to cover small wires. This complete equation, however, is of theoretical interest.

For use over a wide range of frequency and radius of conductor, it is:

$$p = 241\,(f + 25)\sqrt{\frac{r + \dfrac{6}{s} + 0.04}{s}}\,(e - e_d)^2\,10^{-5}$$

$$e_d = g_d\, m_0\, r \log_e \frac{s}{r}$$

$$g_d = 21.2\left(1 + \frac{0.3}{\sqrt{r}}\,\frac{1}{1 + 230\, r^2}\right)$$

Even before the practical size of conductor is reached, $g_d = g_0$ and is constant, or e_0 is constant for all practical sizes. For the smaller sizes g_d increases and finally at zero radius $g_d = g_v$. Prof. Bennett's data should check substantially the above equations.

These equations derived from measurements over a frequency range of 20 to 130 cycles and wide conductor range reduce to (3) for practical size of conductor, spacing, and frequency.

It must always be remembered that there should be no loss below e_v with perfectly smooth conductors. The loss below e_v therefore varies from day to day depending upon irregularities and follows the probability curve. It is not of much practical importance to know this loss, as the storm loss limits the maximum voltage to about fair weather e_0.

In regard to Dr. Whitehead's objection to the energy zone

theory: This theory has helped me in deriving formulas and has therefore been useful. For instance—I probably would not have been able to write the formula connecting visual gradient with radius and pressure if I had not looked upon it in that way. The electron theory is of a great help and will be a greater help, but it is not possible to explain everything by it at the present time.

Edward Bennett: With reference to the question about the double appearance of the voltage curve on films 179 and 180, I would say that is due to a fault in the reproduction of the film. The curve is rather broad.

The use of the string galvanometer has been suggested because it has been assumed that the resistance of the current transformer is excessive. By reference to Fig. 3, however, it will be noted that the resistance of the current transformer and vibrator is only 0.02 megohms, whereas the capacity-reactance between the wire and cylinder in series with which it is connected is 90 megohms, so that the voltage consumed in the current transformer will be a small fraction of one per cent of the total impressed voltage. It is true that the current sensibility of the string galvanometer is extremely high, but it must be remembered that the current sensibility has been obtained at the expense of a long period of vibration, so that the string galvanometer would be absolutely unable to reproduce frequencies of the order we have to reproduce in this case.

With reference to the statement during the discussion that film 183 shows the distortion in the current wave form only when the wire is anode, I would state that it is extremely difficult to detect in the reproduction any distortion in the current wave form during the half cycle when the wire is cathode, but such a distortion can be readily determined on the original films.

John B. Whitehead: It shows here on the reproduction of the film when the wire is anode and not when the wire is cathode.

Edward Bennett: The difference between the appearances of the distortions in the current curves, which makes it difficult to determine whether there is a certain range of voltage over which the distortion occurs only during the half cycle when the wire is the anode, or vice versa, is pointed out in the discussion of film 183.

John B. Whitehead: The only point I want to make is if you have that kick in the current wave, its amplitude is much greater than the amplitude of the disturbance on the other side. It indicates to me if you carry the voltage on down it would simply show the fact on the film as it is shown here.

Edward Bennett: I do not think that necessarily follows, when you consider the other fact developed by the oscillograms, namely, at higher voltages copious ionization starts earlier in the cycle when the wire is cathode than when it is anode. The

direction of the gradient when ionization is first observed, is still, I think, an open question.

With reference to the method of measuring voltages by means of corona, I understand that Professor Ryan has done a great deal of work in which he uses a measuring instrument comprising a conical conductor in a concentric cylinder. This is the only type of instrument with which it would be feasible to measure varying voltages. Suppose you wanted to determine the peak voltages due to surges, etc. It is not feasible to change the inner conductor, as has been suggested, but a conical inner conductor may be used and the point on this conductor at which the corona terminates may be noted. Whether this can be used as an exact indication of the highest voltage, remains to be determined.

It is my understanding that all the equations expressing relation between loss and voltage, between the critical gradient and radius of conductor, etc., are not rigorously exact but are approximate equations.

Messrs. Whitehead and Peek are to be congratulated upon the manner in which they marshalled and analyzed a very large mass of experimental data, and from this have evolved the few elegant relations embodied in the equations expressing the interrelations between power loss, diameter of conductor, air pressure, and impressed voltage. The extension of these empirical relations between the critical intensity, the density factor and the diameter of conductor, which were first worked out for the case of cylinder conductors, to the case of spheres, is a distinct contribution to the subject.

In addition to this contribution the third paper is entitled "A theory of rupture." This theory is advanced in the attempt to account for a discrepancy between our preconceived notions and experimentally determined facts. The preconceived notion is that the computed electric intensity or gradient at which a gas gives experimental evidence of breaking down ought to be a constant. The fact is that the computed gradient, the gradient computed on the assumption that there is no accumulation of charge around the conductors is not a constant, but becomes larger and larger for conductors of smaller and smaller diameters.

After developing the simple relation $g_v = g_0 \left(1 + \frac{k}{\sqrt{r}}\right)$. and noting from this that the computed gradient is always constant and equal to g_0, at a distance of $k \sqrt{r}$ from the surface of the conductor, the simplicity of the relation seems in some way to lead to the conclusion that failure does not occur at the surface, but only after "rupturing energy" has been stored around the wire in a zone between the wire and this hypothetical cylinder at which a constant hypothetical gradient is obtained.

It must be remembered that an analytical expression can be found which will express the distance between the surface of

the conductor and the point at which the computed gradient at the voltage of rupture has any other constant value, as 25 or 20 kilovolts per cm.

Does this fact, however, the fact that an expression can be found for the distance from the surface of conductors to a point where the computed gradients are constant, warrant the interjection of the notion of an energy storage zone? It must be recognized that in the hands of the author of the theory, the notion of the energy storage zone has been very fruitful and has led to some very simple relations, but in the hands of others, or in the mental processes of others, of whom I am one, the notion of an energy storage zone is absolutely fruitless and barren. This may be a fault, not in the notion, but in the mental processes of those to whom the notion is fruitless. To me it is an incident that the expression for the distance between the surface of a conductor and the point at which the gradient is 29.8, or 31, or 33.6 kilovolts assumes a simple form. I have no real quantitative explanation to offer for the relations observed, but in my estimation the fruitful explanation will be based upon statistical relations to be expressed in the language of the atomic structure of electricity.

Alan E. Flowers: The article by Milner was published in Nov. 1912 in the *Philosophical Magazine,* Vol. 24, page 709.

John B. Whitehead: How was that curve obtained?

Alan E. Flowers: Results were obtained by the use of the Braun tube and the sharply defined cathode ray pencil, produced by having two metallic screens, each pierced by a small hole in the center and along the line of the axis of the tube and also perpendicular to the cathode surface, the screens also forming anodes in the tube. Part of the cathode rays, proceeding in a direction normal to the cathode surface, passed through these

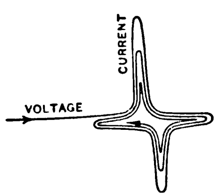

FIG. 2

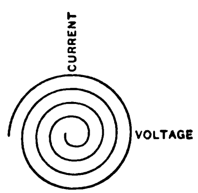

FIG. 3

two holes and were deflected by the magnetic and electric fields of the discharge circuit. The oscillating current through the sphere gap was assumed to be a sine wave and was produced by an induction coil. The primary on this induction coil was in series with the primary of another coil, whose secondary supplied the discharge in the tube, thus making the cathode ray pencil occur in synchronism with the current in the gap circuit. The oscillating current through the gap passed also

through a coil whose axis was at right angles to the tube and "cathode ray pencil" and produced a magnetic field tending to deflect the cathode pencil vertically. Plate electrodes so set that the electric field between them tended to deflect the cathode pencil horizontally, were connected either across the sphere gap or across the supply condensers and consequently deflected the pencil in proportion to the gap voltage or the total voltage of the oscillating circuit. The cathode pencil fell upon a willemite screen and was photographed. In this way, crossed and spiral curves were obtained, such as are shown in Figs. 2 and 3. The photograph showed rather a wide band. A line was then drawn along the middle of the photograph trace and this line-curve analyzed to give the curve shown in Figure 1. The actual record is thus the volt-ampere characteristic, from which, assuming a sine current, the time curves may be calculated. The volt-ampere characteristics obtained when the total oscillating voltage was used, were of spiral or elliptical form, thus checking the assumption of the sine wave discharge.

John B. Whitehead: The Braun tube is perfectly well known.

Alan E. Flowers: This method of getting a volt-ampere curve is, however, new, and gives extremely useful information under the very difficult conditions of extremely high frequency.

William J. Hammer: Professor Whitehead referred to the effect of particles of dust, on the path of the flow; and he also referred to some experiments conducted on the surfaces. It seems to me that the surface characteristics of metal is a matter to which not sufficient attention has been given, where particles may rest on the surface, where the surfaces are irregular or vary in their constitution or formation, or are exposed to effects of oxidation.

I speak of this because of some experiments I made some years ago in conjunction with Professor Campbell of Columbia, at which time we made a large number of microphotographs of metal surfaces and carried out a series of observations upon the physical characteristics of the metals themselves. In certain of these experiments sheets of various metals were put in a trough, which was oscillated for a considerable time. This trough contained lignum vitae balls and powdered pumice stone and the surfaces of the metals were roughened slightly, but very evenly, and many micro-photographs were then made and studied. Many experiments were made upon these metals to show their surface characteristics. As an illustration, I will mention one of these experiments made upon aluminum and zinc. I poured a little collodion on the two surfaces, and as soon as it dried, the collodion peeled off the zinc but it stuck so fast to the aluminum I could not get it off with a penknife blade. There were many other experiments made at the time which were of a good deal of interest and demonstrated that these

surface characteristics of the metal itself are frequently very important.

John B. Whitehead: It has been known for sometime that the corona-forming voltage does not vary at all with the material of the conductor. However, the condition of the surface of the conductor does have a great deal to do with the accuracy and sharpness with which the corona will appear with increasing voltage. Anything in the nature of a dust particle or surface inequality is capable of upsetting the observation. With the visual observation you can usually detect a surface imperfection as a slight brush discharge before the whole uniform corona breaks out. We have studied different surfaces, to find out which are the most permanent as regards oxidation or any other process which may upset the character of the observation.

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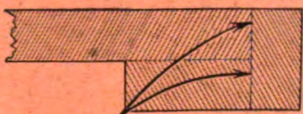
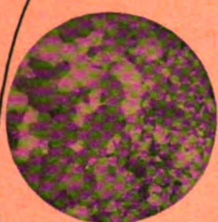
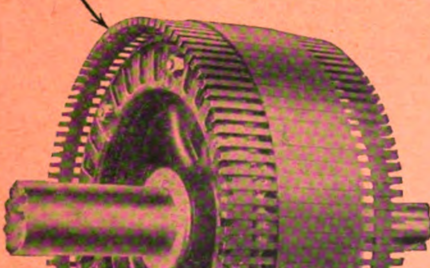
Perfectly Welded Rotor Conductors in G-E Induction Motors



Arrows point to weld.



Microphotograph of section of weld showing homogeneous crystalline structure with no line of demarkation between parts welded.



Form K Rotor Welded Form of End Ring Construction.

Not even a microscope shows the electric welded junction between conductor bar and end ring on the rotor of a G-E squirrel cage induction motor.

In numerous bending tests for strength, rupture has never been at the weld. Under extraordinary overloads the end ring has melted, leaving the welded joint intact.

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